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Additional inventors are being named on the 2nd *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

ANTAGONIST ANTI-CD40 MONOCLONAL ANTIBODIES AND METHODS FOR THEIR USE

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Respectfully submitted,

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ANTAGONIST ANTI-CD40 MONOCLONAL ANTIBODIES AND METHODS FOR THEIR USE

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ANTAGONIST ANTI-CD40 MONOCLONAL ANTIBODIES AND METHODS FOR THEIR USE

FIELD OF THE INVENTION

The invention relates to human antibodies capable of binding to CD40, methods of using the antibodies, and methods for treatment of diseases mediated by stimulation of CD40 signaling on CD40-expressing cells.

BACKGROUND OF THE INVENTION

B cells play an important role during the normal *in vivo* immune response. A foreign antigen will bind to surface immunoglobulins on specific B cells, triggering a chain of events including endocytosis, processing, presentation of processed peptides on MHC-class II molecules, and up-regulation of the B7 antigen on the B cell surface. A specific T cell then binds to the B cell via T cell receptor (TCR) recognition of the processed antigen presented on the MHC-class II molecule. Stimulation through the TCR activates the T cell and initiates T-cell cytokine production. A second signal that further activates the T cell is an interaction between the CD28 antigen on T cells and the B7 antigen on B cells. When the above-mentioned signals are received, the CD40 ligand (CD40L or CD154), which is not expressed on resting human T cells, is up-regulated on the T-cell surface. Binding of the CD40 ligand to the CD40 antigen on the B cell surface stimulates the B cell, causing the B cell to mature into a plasma cell secreting high levels of soluble immunoglobulin.

CD40 is a 55 kDa cell-surface antigen present on the surface of both normal and neoplastic human B cells, dendritic cells, antigen presenting cells (APCs), endothelial cells, monocytic and and epithelial cells. Transformed cells from patients with low- and high-grade B-cell lymphomas, B-cell acute lymphoblastic leukemia, multiple myeloma,

chronic lymphocytic leukemia, and Hodgkin's disease express CD40. CD40 expression is also detected in two-thirds of acute myeloblastic leukemia cases and 50% of AIDS-related lymphomas. Malignant B cells from several tumors of B-cell lineage express a high degree of CD40 and appear to depend on CD40 signaling for survival and proliferation.

Immunoblastic B-cell lymphomas frequently arise in immunocompromised individuals such as allograft recipients and others receiving long-term immunosuppressive therapy, AIDS patients, and patients with primary immunodeficiency syndromes such as X-linked lymphoproliferative syndrome or Wiscott-Aldrich syndrome (Thomas *et al.* (1991) *Adv. Cancer Res.* 57:329; Straus *et al.* (1993) *Ann. Intern. Med.* 118:45).

The CD40 antigen is related to the human nerve growth factor (NGF) receptor, tumor necrosis factor-α (TNF-α) receptor, and Fas, suggesting that CD40 is a receptor for a ligand with important functions in B-cell activation. CD40 expression on APCs plays an important co-stimulatory role in the activation of both T-helper and cytotoxic T lymphocytes. The CD40 receptor is expressed on activated T cells, activated platelets, and inflamed vascular smooth muscle cells. CD40 receptors can also be found on eosinophils, synovial membranes in rheumatoid arthritis, dermal fibroblasts, and other non-lymphoid cell types. Binding of CD40L to the CD40 receptor stimulates B-cell proliferation and differentiation, antibody production, isotype switching, and B-cell memory generation.

BRIEF SUMMARY OF THE INVENTION

Compositions and methods are provided for treating diseases mediated by stimulation of CD40 signaling on CD40-expressing cells, including lymphomas, autoimmune diseases, and transplant rejections. Compositions include monoclonal antibodies capable of binding to a human CD40 antigen located on the surface of a human CD40-expressing cell, wherein the binding prevents the growth or differentiation of the cell. Compositions also include monoclonal antibodies capable of specifically binding to a human CD40 antigen expressed on the surface of a human CD40-expressing cell, said monoclonal antibody being free of significant agonistic activity, wherein

administration of said monoclonal antibody results in significantly less tumor volume than a similar concentration of the chimeric anti-CD20 monoclonal antibody IDEC-C2B8 in a staged nude mouse xenograft tumor model using the Daudi human B cell lymphoma cell line. Compositions also include antigen-binding fragments of these monoclonal antibodies, hybridoma cell lines producing these antibodies, and isolated nucleic acid molecules encoding the amino acid sequences of these monoclonal antibodies. The invention further includes pharamaceutical compositions comprising the such anti-CD40 antibodies in a pharmaceutically acceptable carrier.

Methods are provided for preventing or treating a disease mediated by stimulation of CD40 signaling, comprising treating the patient with an anti-CD40 antibody or an antigen-binding fragment thereof that is free of significant agonist activity when bound to a CD40 antigen on a human CD40-expressing cell. Diseases mediated by stimulation of CD40-expressing cells include autoimmune diseases, cancers, and organ and tissue graft rejections. Lymphomas that can be treated or prevented by a method of the present invention include non-Hodgkin's lymphomas (high-grade lymphomas, intermediate-grade lymphomas, and low-grade lymphomas), Hodgkin's disease, acute lymphoblastic leukemias, myelomas, chronic lymphocytic leukemias, and myeloblastic leukemias.

Particular autoimmune diseases contemplated for treatment using the methods of the invention include systemic lupus erythematosus (SLE), rheumatoid arthritis, Crohn's disease, psoriasis, autoimmune thrombocytopenic purpura, multiple sclerosis, ankylosing spondylitis, myasthenia gravis, and pemphigus vulgaris. Such antibodies could also be used to prevent rejection of organ and tissue grafts by suppressing autoimmune responses, to treat lymphomas by depriving malignant B lymphocytes of the activating signal provided by CD40, and to deliver toxins to CD40-bearing cells in a specific manner.

Methods for inhibiting the growth, differentiation, and/or proliferation of human B cells and for inhibiting antibody production by B cells in a human patient are provided, as are methods for inhibiting the growth of cancer cells of a B-cell lineage. Methods for identifying antibodies that have antagonistic activity toward CD40-expressing cells are also provided.

The monoclonal antibodies disclosed herein have a strong affinity for CD40 and are characterized by a dissociation equilibrium constant (K_D) of at least 10^{-6} M, preferably at least about 10^{-7} M to about 10^{-8} M, more preferably at least about 10^{-8} M to about 10^{-12} M. Monoclonal antibodies and antigen-binding fragments thereof that are suitable for use in the methods of the invention are capable of specifically binding to a human CD40 antigen expressed on the surface of a human cell. They are free of significant agonist activity but exhibit antagonist activity when bound to CD40 antigen on human cells. In one embodiment, the anti-CD40 antibody or fragment thereof exhibits antagonist activity when bound to CD40 antigen on normal human B cells. In another embodiment, the anti-CD40 antibody or fragment thereof exhibits antagonist activity when bound to CD40 antigen on malignant human B cells. Suitable monoclonal antibodies have human constant regions; preferably they also have wholly or partially humanized framework regions; and most preferably are fully human antibodies or antigen-binding fragments thereof. Examples of such monoclonal antibodies are the antibodies designated herein as 5.9 and 12.12; the monoclonal antibodies produced by the hybridoma cell lines designated 131.2F8.5.9 (referred to herein as the cell line 5.9) and 153.8E2.D10.D6.12.12 (referred to herein as the cell line 12.12); a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 11A, the sequence shown in Fig. 11B, and both the sequence shown in Fig. 11A and 11B; a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and 10B; a monoclonal antibody comprising an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and 12B; and antigen-binding fragments of these monoclonal antibodies that retain the capability of specifically binding to human CD40, and which are free of significant agonist activity but exhibit antagonist activity when bound to CD40 antigen on human cells. Examples of such monoclonal antibodies also include a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 12.12; a monoclonal antibody that binds to an epitope comprising residues 82-87 of the amino

acid sequence shown in Fig. 13B; a monoclonal antibody that competes with the monoclonal antibody 12.12 in a competitive binding assay; and a monoclonal antibody that is an antigen-binding fragment of the 12.12 monoclonal antibody or any of the foregoing monoclonal antibodies, where the fragment retains the capability of specifically binding to the human CD40 antigen.

In one embodiment of the invention, methods of treatment comprise administering to a patient a therapeutically effective dose of a pharmaceutical composition comprising suitable antagonistic anti-CD40 antibodies or antigen-binding fragments thereof. A therapeutically effective dose of the anti-CD40 antibody or fragment thereof is in the range from about 0.01 mg/kg to about 40 mg/kg, from about 0.01 mg/kg to about 30 mg/kg, from about 0.1 mg/kg to about 30 mg/kg, from about 1 mg/kg to about 30 mg/kg, from about 3 mg/kg to about 30 mg/kg, from about 3 mg/kg to about 25 mg/kg, from about 3 mg/kg to about 20 mg/kg, from about 5 mg/kg to about 15 mg/kg, or from about 7 mg/kg to about 12 mg/kg. It is recognized that the method of treatment may comprise a single administration of a therapeutically effective dose or multiple administrations of a therapeutically effective dose of the antagonist anti-CD40 antibody or antigen-binding fragment thereof.

The antagonist anti-CD40 antibodies identified herein as being suitable for use in the methods of the invention may be modified. Modifications of these antagonist anti-CD40 antibodies include, but are not limited to, immunologically active chimeric anti-CD40 antibodies, humanized anti-CD40 antibodies, and immunologically active murine anti-CD40 antibodies.

The following embodiments are encompassed by the present invention:

1. A human monoclonal antibody that is capable of specifically binding to a human CD40 antigen expressed on the surface of a human CD40-expressing cell, said monoclonal antibody being free of significant agonistic activity, wherein said monoclonal antibody exhibits increased anti-tumor activity relative to an equivalent amount of the monoclonal chimeric anti-CD20 monoclonal antibody IDEC-C2B8, wherein said anti-tumor activity is assayed in a staged nude mouse xenograft tumor model using the Daudi human B cell lymphoma cell line.

2. The human monoclonal antibody of embodiment 1, wherein said antibody is selected from the group consisting of:

a) the monoclonal antibody 12.12;

b) the monoclonal antibody produced by the hybridoma cell line 12.12, deposited with the ATCC as Patent Deposit No. PTA-5543;

c) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

d) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

e) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 12.12;

f) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

g) a monoclonal antibody that competes with the monoclonal antibody 12.12 in a competitive binding assay; and,

h) a monoclonal antibody that is an antigen-binding fragment of a monoclonal antibody of a)-g), wherein said fragment retains the capability of specifically binding to said human CD40 antigen.

3. The monoclonal antibody of embodiment 1, wherein said monoclonal antibody binds to said human CD40 antigen with an affinity (K_D) of at least about 10^{-6} M to about 10^{-12} M.

4. A hybridoma cell line capable of producing the monoclonal antibody of embodiment 1.

5. A method for treating a cancer characterized by expression of CD40, comprising administering to a human patient an effective amount of a human anti-CD40 monoclonal antibody of embodiment 1.

6. The method of embodiment 5, wherein said cancer is selected from the group consisting of a non-Hodgkins lymphoma, chronic lymphocytic leukemia, multiple myeloma, B cell lymphoma, high-grade B cell lymphoma, intermediate-grade B cell lymphoma, low-grade B cell lymphoma, B cell acute lympohoblastic leukemia, myeloblastic leukemia, and Hodgkin's disease.

7. A human monoclonal antibody that is capable of specifically binding to a human CD40 antigen expressed on the surface of a human CD40-expressing cell, said monoclonal antibody being free of significant agonistic activity, whereby, when said monoclonal antibody binds to the CD40 antigen expressed on the surface of said cell, the growth or differentiation of said cell is inhibited, wherein said antibody is selected from the group consisting of:

a) the monoclonal antibody 5.9 or 12.12;

b) the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

c) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 11A, the sequence shown in Fig. 11B, and both the sequence shown in Fig. 11A and Fig. 11B;

d) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

e) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

f) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

g) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

h) a monoclonal antibody that binds to an epitope comprising residues 82-89 of the human CD40 sequence shown in Fig. 13B;

i) a monoclonal antibody that competes with the monoclonal antibody 5.9 or 12.12 in a competitive binding assay; and,

j) a monoclonal antibody that is an antigen-binding fragment of a monoclonal antibody of a)-j), wherein said fragment retains the capability of specifically binding to said human CD40 antigen.

8. The antigen-binding fragment of embodiment 7, wherein said fragment is selected from the group consisting of a Fab fragment, an $F(ab')_2$ fragment, an Fv fragment, and a single-chain Fv fragment.

9. The monoclonal antibody of embodiment 7, wherein said monoclonal antibody binds to said human CD40 antigen with an affinity (K_D) of at least about 10^{-6} M to about 10^{-12} M.

10. An isolated nucleic acid molecule comprising a polynucleotide that encodes an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, Fig. 10B, Fig. 11A, and Fig. 11B..

11. A hybridoma cell line capable of producing a human monoclonal antibody having specificity for a human CD40 antigen expressed on the surface of a human CD40-expressing cell, whereby said monoclonal antibody is free of significant agonistic activity, whereby, when said monoclonal antibody binds to the CD40 antigen expressed on the surface of said cell, the growth or differentiation of said cell is inhibited, and wherein said monoclonal antibody is selected from the group consisting of:

a) the monoclonal antibody 5.9 or 12.12;

b) the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

c) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 11A, the sequence shown in Fig. 11B, and both the sequence shown in Fig. 11A and Fig. 11B;

d) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

e) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

f) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

g) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

h) a monoclonal antibody that binds to an epitope comprising residues 82-89 of the human CD40 sequence shown in Fig. 13B;

i) a monoclonal antibody that competes with the monoclonal antibody 5.9 or 12.12 in a competitive binding assay; and,

j) a monoclonal antibody that is an antigen-binding fragment of a monoclonal antibody of a)-j), wherein said fragment retains the capability of specifically binding to said human CD40 antigen.

12. A method for inhibiting growth or differentiation of a normal human B cell, comprising contacting said B cell with an effective amount of a human anti-CD40 monoclonal antibody selected from the group consisting of:

a) the monoclonal antibody 5.9 or 12.12;

b) the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

c) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 11A, the sequence shown in Fig. 11B, and both the sequence shown in Fig. 11A and Fig. 11B;

d) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

e) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

f) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

g) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

h) a monoclonal antibody that binds to an epitope comprising residues 82-89 of the human CD40 sequence shown in Fig. 13B;

i) a monoclonal antibody that competes with the monoclonal antibody 5.9 or 12.12 in a competitive binding assay; and;

j) a monoclonal antibody that is an antigen-binding fragment of a monoclonal antibody of a)-j), wherein said fragment retains the capability of specifically binding to said human CD40 antigen;

said antibody or fragment thereof being free of significant agonistic activity, and whereby when said antibody or fragment thereof binds to said CD40 antigen on said B cell, the growth or differentiation of said B cell is inhibited.

13. The method of embodiment 12, wherein said monoclonal antibody or fragment thereof binds to said human CD40 antigen with an affinity (K_D) of at least about 10^{-6} M to about 10^{-12} M.

14. The method of embodiment 12, wherein said fragment is selected from the group consisting of a Fab fragment, an $F(ab')_2$ fragment, an Fv fragment, and a single-chain Fv fragment.

15. A method for inhibiting proliferation of a normal human B cell, wherein said proliferation is augmented by the interaction of a CD40 ligand with a CD40 antigen expressed on the surface of said B cell, said method comprising contacting said B cell with an effective amount of a human anti-CD40 monoclonal antibody selected from the group consisting of:

a) the monoclonal antibody 5.9 or 12.12;

b) the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

c) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 11A, the sequence shown in Fig. 11B, and both the sequence shown in Fig. 11A and Fig. 11B;

d) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

e) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

f) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

g) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

h) a monoclonal antibody that binds to an epitope comprising residues 82-89 of the human CD40 sequence shown in Fig. 13B;

i) a monoclonal antibody that competes with the monoclonal antibody 5.9 or 12.12 in a competitive binding assay; and,

j) a monoclonal antibody that is an antigen-binding fragment of a monoclonal antibody of a)-j), wherein said fragment retains the capability of specifically binding to said human CD40 antigen;

said antibody or fragment thereof being free of significant agonistic activity, and whereby when said antibody or fragment thereof binds to said CD40 antigen on said B cell, the growth or differentiation of said B cell is inhibited.

16. The method of embodiment 15, wherein said monoclonal antibody binds to said human CD40 antigen with an affinity (K_D) of at least about 10^{-6} M to about 10^{-12} M.

17. The method of embodiment 15, wherein said fragment is selected from the group consisting of a Fab fragment, an $F(ab')_2$ fragment, an Fv fragment, and a single-chain Fv fragment.

18. A method for inhibiting antibody production by B cells in a human patient, comprising administering to a human patient an effective amount of a human anti-CD40 monoclonal antibody or fragment thereof selected from the group consisting of:

a) the monoclonal antibody 5.9 or 12.12;

b) the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

c) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 11A, the sequence shown in Fig. 11B, and both the sequence shown in Fig. 11A and Fig. 11B;

d) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

e) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

f) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

g) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

h) a monoclonal antibody that binds to an epitope comprising residues 82-89 of the human CD40 sequence shown in Fig. 13B;

i) a monoclonal antibody that competes with the monoclonal antibody 5.9 or 12.12 in a competitive binding assay; and,

j) a monoclonal antibody that is an antigen-binding fragment of a monoclonal antibody of a)-j), wherein said fragment retains the capability of specifically binding to said human CD40 antigen;

said antibody or fragment thereof being free of significant agonistic activity, and whereby when said antibody or fragment thereof binds to said CD40 antigen on said B cell, the growth or differentiation of said B cell is inhibited.

19. The method of embodiment 18, wherein said monoclonal antibody binds to said human CD40 antigen with an affinity (K_D) of at least about 10^{-6} M to about 10^{-12} M.

20. The method of embodiment 18, wherein said fragment is selected from the group consisting of a Fab fragment, an $F(ab')_2$ fragment, an Fv fragment, and a single-chain Fv fragment.

21. A method for inhibiting growth of cancer cells of B cell lineage, comprising contacting said cancer cells with an effective amount of a human anti-CD40 monoclonal antibody selected from the group consisting of:

a) the monoclonal antibody 5.9 or 12.12;

b) the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

c) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 11A, the sequence shown in Fig. 11B, and both the sequence shown in Fig. 11A and Fig. 11B;

d) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

e) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

f) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

g) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

h) a monoclonal antibody that binds to an epitope comprising residues 82-89 of the human CD40 sequence shown in Fig. 13B;

i) a monoclonal antibody that competes with the monoclonal antibody 5.9 or 12.12 in a competitive binding assay; and,

j) a monoclonal antibody that is an antigen-binding fragment of a monoclonal antibody of a)-j), wherein said fragment retains the capability of specifically binding to said human CD40 antigen;

said antibody or fragment thereof being free of significant agonistic activity, and whereby when said antibody or fragment thereof binds to said CD40 antigen on said B cell, the growth or differentiation of said B cell is inhibited.

22. The method of embodiment 21, wherein said monoclonal antibody binds to said human CD40 antigen with an affinity (K_D) of at least about 10^{-6} M to about 10^{-12} M.

23. The method of embodiment 21, wherein said fragment is selected from the group consisting of a Fab fragment, an $F(ab')_2$ fragment, an Fv fragment, and a single-chain Fv fragment.

24. The method of embodiment 21, wherein the cancer is selected from the group consisting of non-Hodgkins lymphoma, chronic lymphocytic leukemia, multiple myeloma, B cell lymphoma, high-grade B cell lymphoma, intermediate-grade B cell lymphoma, low-grade B cell lymphoma, B cell acute lympohoblastic leukemia, myeloblastic leukemia, and Hodgkin's disease.

25. A method for treating an autoimmune disease, comprising administering to a human patient an effective amount of a human anti-CD40 monoclonal antibody selected from the group consisting of:

a) the monoclonal antibody 5.9 or 12.12;

b) the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

c) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 11A, the sequence shown in Fig. 11B, and both the sequence shown in Fig. 11A and Fig. 11B;

d) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

e) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

f) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

g) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

h) a monoclonal antibody that binds to an epitope comprising residues 82-89 of the human CD40 sequence shown in Fig. 13B;

i) a monoclonal antibody that competes with the monoclonal antibody 5.9 or 12.12 in a competitive binding assay; and,

j) a monoclonal antibody that is an antigen-binding fragment of a monoclonal antibody of a)-j), wherein said fragment retains the capability of specifically binding to said human CD40 antigen;

said antibody or fragment thereof being free of significant agonistic activity, and whereby when said antibody or fragment thereof binds to said CD40 antigen on said B cell, the growth or differentiation of said B cell is inhibited.

26. The method of embodiment 25, wherein said monoclonal antibody binds to said human CD40 antigen with an affinity (K_D) of at least about 10^{-6} M to about 10^{-12} M.

27. The method of embodiment 25, wherein said fragment is selected from the group consisting of a Fab fragment, an $F(ab')_2$ fragment, an Fv fragment, and a single-chain Fv fragment.

28. The method of embodiment 25, wherein said autoimmune disease is selected from the group consisting of systemic lupus erythematosus, autoimmune thrombocytopenic purpura, Rhematoid arthritis, multiple sclerosis, ankylosing spondylitis, myasthenia gravis, and pemphigus vulgaris.

29. A method for treating a cancer characterized by expression of CD40, comprising administering to a human patient an effective amount of a human anti-CD40 monoclonal antibody selected from the group consisting of:

a) the monoclonal antibody 5.9 or 12.12;

b) the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

c) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 11A, the sequence shown in Fig. 11B, and both the sequence shown in Fig. 11A and Fig. 11B;

d) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

e) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

f) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

g) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

h) a monoclonal antibody that binds to an epitope comprising residues 82-89 of the human CD40 sequence shown in Fig. 13B;

i) a monoclonal antibody that competes with the monoclonal antibody 5.9 or 12.12 in a competitive binding assay; and,

j) a monoclonal antibody that is an antigen-binding fragment of a monoclonal antibody of a)-j), wherein said fragment retains the capability of specifically binding to said human CD40 antigen;

said antibody or fragment thereof being free of significant agonistic activity, and whereby when said antibody or fragment thereof binds to said CD40 antigen on said B cell, the growth or differentiation of said B cell is inhibited.

30. The method of embodiment 29, wherein said monoclonal antibody binds to said human CD40 antigen with an affinity (K_D) of at least about 10^{-6} M to about 10^{-12} M.

31. The method of embodiment 29, wherein said fragment is selected from the group consisting of a Fab fragment, an $F(ab')_2$ fragment, an Fv fragment, and a single-chain Fv fragment.

32. A method for identifying an antibody that has antagonistic activity toward CD40-expressing cells, comprising performing a competitive binding assay with a monoclonal antibody selected from the group consisting of:

a) the monoclonal antibody 5.9 or 12.12;

b) the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

c) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 11A, the sequence shown in Fig. 11B, and both the sequence shown in Fig. 11A and Fig. 11B;

d) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

e) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

f) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 5.9 or 12.12;

g) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

h) a monoclonal antibody that binds to an epitope comprising residues 82-89 of the human CD40 sequence shown in Fig. 13B; and

i) a monoclonal antibody that is an antigen-binding fragment of a monoclonal antibody of a)-j), wherein said fragment retains the capability of specifically binding to said human CD40 antigen..

33. An antagonist anti-CD40 monoclonal antibody that specifically binds Domain 2 of CD40.

34. The monoclonal antibody of claim 33, wherein said antibody is a human antibody.

35. The monoclonal antibody of claim 34, wherein said antibody is free of significant agonist activity.

36. The monoclonal antibody of claim 33, wherein said antibody has the binding specificity of an antibody selected from the group consisting of the antibody produced by hybridoma cell line 5.9 and the antibody produced by hybridoma cell line 12.12.

37. The monoclonal antibody of claim 33, wherein said antibody is selected from the group consisting of the antibody produced by hybridoma cell line deposited with the ATCC as Patent Deposit No. PTA -5542 and hybridoma cell line deposited with the ATCC as Patent Deposit No. PTA-5543.

38. The monoclonal antibody of claim 33, wherein said antibody has the binding specificity of monoclonal antibody 12.12 or 5.9.

39. The monoclonal antibody of claim 33, wherein said antibody binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B.

40. The monoclonal antibody of claim 33, wherein said antibody is selected from the group consisting of:

a) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the sequence shown in Fig. 10A, the sequence shown in Fig. 10B, and both the sequence shown in Fig. 10A and Fig. 10B;

b) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the sequence shown in Fig. 12A, the sequence shown in Fig. 12B, and both the sequence shown in Fig. 12A and Fig. 12B;

c) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 12.12;

d) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the human CD40 sequence shown in Fig. 13B;

e) a monoclonal antibody that competes with the monoclonal antibody 12.12 in a competitive binding assay; and

f) a monoclonal antibody that is an antigen-binding fragment of the 12.12 monoclonal antibody or the foregoing monoclonal antibodies in preceding items (1)-(6), where the fragment retains the capability of specifically binding to the human CD40 antigen.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows binding of 5.9 and 12.12 monoclonal antibodies to CD40 on the surface of lymphoma cell line (Ramos).

Figure 2 illustrates the substantial variation in the sequences in the complementarity determining regions (CDRs) that is to be expected for antibodies derived from independent hybridomas. Figure 2A shows the amino acid sequences for the heavy chains for the monoclonal antibodies 5.9 (see also Fig. 11B), 12.12 (see also Fig. 10B), and 15B8. Figure 2B shows the amino acid sequences for the light chains for the monoclonal antibodies 5.9 (see also 11A), 12.12 (see also 10A), and 15B8.

Figures 3A and 3B illustrate binding properties of the 5.9 and 12.12 monoclonal anti-CD40 antibodies relative toCD40 ligand. Figure 3A shows that binding of 5.9 and 12.12 monoclonal antibodies to cell surface CD40 prevents subsequent CD40-ligand binding. Figure 3B shows that the 5.9 and 12.12 monoclonal antibodies can compete off CD40 ligand pre-bound to cell surface CD40.

Figures 4A and 4B show ADCC activity of the candidate monoclonal antibodies 5.9 and 12.12 against cancer cells from the lymph nodes of non-Hodgkin's lymphoma (NHL) patients. Enriched NK cells from a normal volunteer donor either fresh after isolation (Figure 4A) or after culturing overnight at 37°C (Figure 4B) were used as effector cells in this assay. As NHL cells also express CD20, the target antigen for rituximab (Rituxa®), ADCC activity of the candidate mAbs was compared with that of rituximab.

Figure 5 demonstrates *in vivo* anti-tumor activity of monoclonal antibodies 5.9 and 12.12 compared to that of rituximab using an unstaged nude mouse xenograft B cell lymphoma (Namalwa) model.

Figure 6 demonstrates *in vivo* anti-tumor activity of monoclonal antibodies 5.9 and 12.12 compared to that of rituximab using an unstaged nude mouse xenograft B cell lymphoma (Daudi) model.

Figure 7 demonstrates *in vivo* anti-tumor activity of monoclonal antibodies 5.9 and 12.12 compared to that of rituximab using a staged nude mouse xenograft B cell lymphoma (Daudi) model.

Figure 8 shows the protocol used for determining the number of CD20 and CD40 molecules on Namalwa and Daudi cells.

Figure 9 shows comparative ADCC of the mAb 12.12 and rituximab against Daudi lymphoma cells.

Figure 10 shows the amino acid sequence for the light chain (Fig. 10A) and heavy chain (Fig. 10B) for the mAb 12.12.

Figure 11 shows the amino acid sequence for the light chain (Fig. 11A) and heavy chain (Fig. 11B) for the mAb 5.9.

Figure 12 shows the coding sequence for the light chain (Fig. 12A) and heavy chain (Fig. 12B) for the mAb 12.12.

Figure 13 shows the coding sequence (Fig. 13A) for human CD40 (amino acid sequence shown in Fig. 13B).

DETAILED DESCRIPTION OF THE INVENTION

"Tumor", as used herein, refers to all neoplastic cell growth and proliferation, whether malignant or benign, and all pre-cancerous and cancerous cells and tissues.

The terms "cancer" and "cancerous" refer to or describe the physiological condition in mammals that is typically characterized by unregulated cell growth. Examples of cancer include but are not limited to lymphoma and leukemia.

"Antibodies" and "immunoglobulins" (Igs) are glycoproteins having the same structural characteristics. While antibodies exhibit binding specificity to an antigen, immunoglobulins include both antibodies and other antibody-like molecules that lack

antigen specificity. Polypeptides of the latter kind are, for example, produced at low levels by the lymph system and at increased levels by myelomas.

The term "antibody" is used in the broadest sense and covers fully assembled antibodies, antibody fragments that can bind antigen (e.g., Fab', F'(ab)$_2$, Fv, single chain antibodies, diabodies), and recombinant peptides comprising the forgoing.

The term "monoclonal antibody" as used herein refers to an antibody obtained from a population of substantially homogeneous antibodies, i.e., the individual antibodies comprising the population are identical except for possible naturally-occurring mutations that may be present in minor amounts.

"Native antibodies" and "native immunoglobulins" are usually heterotetrameric glycoproteins of about 150,000 daltons, composed of two identical light (L) chains and two identical heavy (H) chains. Each light chain is linked to a heavy chain by one covalent disulfide bond, while the number of disulfide linkages varies among the heavy chains of different immunoglobulin isotypes. Each heavy and light chain also has regularly spaced intrachain disulfide bridges. Each heavy chain has at one end a variable domain (VH) followed by a number of constant domains. Each light chain has a variable domain at one end (V,) and a constant domain at its other end; the constant domain of the light chain is aligned with the first constant domain of the heavy chain, and the light chain variable domain is aligned with the variable domain of the heavy chain. Particular amino acid residues are believed to form an interface between the light and heavy-chain variable domains.

The term "variable" refers to the fact that certain portions of the variable domains differ extensively in sequence among antibodies and are used in the binding and specificity of each particular antibody for its particular antigen. However, the variability is not evenly distributed throughout the variable domains of antibodies. It is: concentrated in three segments called complementarity determining regions (CDRs) or hypervariable regions both in the light chain and the heavy-chain variable domains. The more highly conserved portions of variable domains are celled the framework (FR) regions. The variable domains of native heavy and light chains each comprise four FR regions, largely adopting a p-sheet configuration, connected by three CDRs, which form loops connecting, and in some cases forming part of, the p-sheet structure. The CDRs

in each chain are held together in close proximity: by the FR regions and, with the CDRs from the other chain, contribute to the formation of the antigen-binding site: of antibodies (see Kabat et al., NIH Publ. No.91-3242, Vol. I, pages 647-669 (1991)).

The constant domains are not involved directly in binding an antibody to an antigen, but exhibit various effecter functions, such as participation of the antibody in antibody-dependent cellular toxicity.

The term "hypervariable region" when used herein refers to the amino acid residues of an antibody which: are responsible for antigen-binding. The hypervariable region comprises amino acid residues from a "complementarily determining region" or" CDR" (i.e., residues 24-34 (L1),50-56 (L2) and89-97 (L3) in the light chain variable domain and 31-35 (H1), 50-65 (H2) and 95-102 (H3) in the heavy chain variable domain; Kabat *et al.*, *Sequences of Proteins of Immunological Interest*, 5th Ed. Public Health Service, National Institute of Health, i 25 Bethesda, MD. [1991]) and/or those residues from a "hypervariable loop" (i.e., residues 26-32(L1), 50-52 (L2) and 91-96 (L3) in the light chain variable domain and2632(H1), 53-55 (H2) and 96-101 (H3) in the heavy chain variable domain; Clothia and Lesk, J. Mol. Biol., 196:901 -917 [1987]). "Framework" or "FR" residues are those variable domain residues other than the hypervariable region residues as herein deemed.

"Antibody fragments" comprise a portion of an intact antibody, preferably the antigen binding or variable region of the intact antibody. Examples of antibody fragments include Fab, Fab', F(ab')2, and Fv fragments; diabodies; linear antibodies (Zapata et al., Protein Eng.,8(10):1057-1062 [1995]); single-chain antibody molecules; and multispecific antibodies formed from antibody fragments. Papain digestion of antibodies produces two identical antigen-binding fragments, called "Fab" fragments, each with a single antigen-binding site, and a residual "Fc" fragment, whose name reflects its ability to crystallize 35 readily. Pepsin treatment yields an F(ab')2 fragment that has two antigen-combining sites and is still capable of cross-linking antigen.

"Fv" is the minimum antibody fragment that contains a complete antigen recognition and binding site. This region consists of a dimer of one heavy- and one light-chain variable domain in tight, non-covalent association. It is in this configuration that the three CDRs of each variable domain interact to define an antigen binding site on the

surfaceof the VH VI dimer. Collectively, the six CDRs confer antigen-binding specificity to the antibody. However, even a single variable domain (or half of an Fv comprising only three CDRs specific for an antigen) has the ability to recognize and bind antigen, although at a lower affinity than the entire binding site.

The Fab fragment also contains the constant domain of the light chain and the first constant domain (CH1) of the heavy chain. Fab fragments differ from Fab' fragments by the addition of a few residues at the carboxy terminus of the heavy chain CH 1 domain including one or more cysteines from the antibody hinge region .Fab'-SH is the designation herein for Fab' in which the cysteine residue(s) of the constant domains bear a f ee thiol group. F(ab')2antibody fragments originally were produced as pairs of Fab' fragmentswhich have hinge cysteines between them.

Other chemical couplings of antibody fragments are also known. The "light chains" of antibodies (immunoglobulins) from any vertebrate species can be assigned to one of two clearly distinct types, called kappa (k) and lambda (l), based on the amino acid sequences of their constant domains.

Depending on the amino acid sequence of the constant domain of their heavy chains, immunoglobulins can be assigned to different classes. There are five major classes of immunoglobulins: IgA,I gD, IgE, IgG, and IgM, and several of these may be further divided intosubclasses (isotypes), e.g., IgG1, IgG2, IgG3, IgG4, IgA, and IgA2. The heavy-chain constant domains that correspond to the different classes of immunoglobulins are called alpha, delta, epsilon gamma, and mu respectively. The subunit structures and three-dimensional configurations of different classes of immunoglobulins are well known. Different isotypes have different effector functions. For example, IgG1 and IgG3 isotypes have ADCC activity.

"Fv" is the minimum antibody fragment that contains a complete antigen recognition and binding site. In a two-chain Fv species, this region consists of a dimer of one heavy- and one light chain variable domain in tight, non-covalent association. In a single-chain Fv species, one heavy and one light-chain variable domain can be covalently linked by flexible peptide linker such that the light and heavy chains can associate in a "dimeric" structure analogous to that in a two-chain Fv 35species. It is in this configuration that the three CDRs of each variable domain interact to define an antigen-

binding site on the surface of the VH-VL dimer. Collectively, the six CDRs confer antigen-binding specificity to the antibody. However, even a single variable domain (or half of an Fv comprising only three CDRs specific for an antigen) has the ability to recognize and bind antigen, although at a lower affinity than the entire binding site.

The word "label" when used herein refers to a detectable compound or composition that is conjugated directly or indirectly to the antibody so as to generate a "labeled" antibody. The label may be detectable by itself (e.g., radioisotope labels or fluorescent labels) or, in the case of an enzymatic label, may catalyze chemical alteration of a substrate compound or composition that is detectable. Radionuclides that can serve as detectable labels include, for example, I-131, I-123, I-125,Y-90, Re-188, Re-186, At-211, Cu-67, Bi-212, andPd-109. The label might also be a non-detectable entity such as a toxin.

The term "antagonist" is used in the broadest sense, and includes any molecule that partially or fully blocks, inhibits, or neutralizes a biological activity of a native] target disclosed herein or the transcription or translation thereof.

"Carriers" as used herein include pharmaceutically acceptable carriers, excipients, or stabilizers which are nontoxic to the cell or mammal being exposed thereto at the dosages and concentrations employed. Often the physiologically acceptable carrier is an aqueous pH buffered solution. Examples of physiologically acceptable carriers include buffers such as phosphate, citrate, and other organic acids; antioxidants including ascorbic acid; low molecular weight (less than about 10 residues) polypeptides; proteins, such as serum albumin, gelatin, or immunoglobulins; hydrophilic polymers such as polyvinylpyrrolidone; amino acids such as glycine, glutamine, asparagine, arginine or lysine; monosaccharides, disaccharides, and other carbohydrates including glucose, mannose, or dextrins; chelating agents such as EDTA; sugar alcohols such as mannitol or sorbitol; salt-forming counterions such as sodium; and/ornonionic surfactants such as TWEEN, polyethylene glycol (PEG), and PEURONICS. Administration "in combination with" one or more further therapeutic agents includes simultaneous (concurrent) and consecutive administration in any order.

A "host cell", as used herein, refers to a microorganism or a eukaryotic cell or cell line cultured as a unicellular entity which can be, or has been, used as a recipient for a

recombinant vector or other transfer polynucleotides, and include the progeny of the original cell which has been transfected. It is understood that the progeny of a single cell may not necessarily be completely identical in morphology or in genomic or total DNA complement as the original parent, due to natural, accidental, or deliberate mutation. "Human effector cells" are leukocytes that express one or more FcRs and perform effector functions. Preferably, the cells express at least FcγRIII and carry out antigen-dependent cell-mediated cyotoxicity (ADCC) effector function. Examples of human leukocytes that mediate ADCC include peripheral blood mononuclear cells (PBMC), natural killer (NK) cells, monocytes, cytotoxic T cells and neutrophils; with PBMCs and NK cells being preferred. Antibodies that have ADCC activity are typically of the IgG1 or IgG3 isotype. Note that in addition to isolating IgG1 and IgG3 antibodies, such ADCC mediating antibodies can be made by engineering a variable region from a non-ADCC antibody or variable region fragment onto an IgG1 or IgG3 isotype constant region.

The terms "Fc receptor" or "FCR" are used to describe a receptor that binds to the Fc region of an antibody. The preferred FcR is a native sequence human FcR. Moreover, a preferred FcR is one that binds an IgG antibody (a gamma receptor) and includes receptors of the FcγRI, FcγRII, and Fcγ RIII subclasses, including allelic variants and alternatively spliced forms of these receptors. FcγRII receptors include FcγRIIA (an "activating receptor") and FcγRIIB (an "inhibiting receptor"), which have similar amino acid sequences that differ primarily in the cytoplasmic domains thereof. Activating receptor FcγRIIA contains an immunoreceptor tyrosine-based activation motif (ITAM) in its cytoplasmic domain. Inhibiting receptor FcγRIIB contains an immunoreceptor tyrosine-based inhibition motif (ITIM) in its cytoplasmic domain. (see Daeron, Annu. Rev. Immunol. 15:203-234 (1997)). FcRs are reviewed in Ravetch and Kinet, Annu. Rev. Immunol 9:457-92 (1991); Capel et al., Immunomethods 4:25-34 (1994); and de Haas et al., J. Lab. Clin. Med. 126:330-41 (1995). Other FcRs, including those to be identified in the future, are encompassed by the term "FCR" herein. The term also includes the neonatal receptor, FcRn, which is responsible for the transfer of maternal IgGs to the fetus (Guyer et al., J. Immunol. 117:587 (1976) and Kim et al., J. Immunol. 24:249 (1994)).

There are a number of ways to make human antibodies. For example, secreting cells can be immortalized by infection with the Epstein-Barr virus (EBV). However, EBV-infected cells are difficult to clone and usually produce only relatively low yields of immunoglobulin (James and Bell, J. Immunol. Methods 100: 5-40 [1987]). In future, theimmortalization of human B cells might possibly be achieved by introducing a defined combination of transforming genes. Such a possibility is highlighted by a recent demonstration that the expression of the telomerase catalytic subunit together with the SV40 large oncoprotein and an oncogenic allele of H-ras resulted in the tumorigenic conversion of normal human epithelial and fibroblast cells (Hahn et al., Nature 400: 464-468 [1999]).It is now possible to produce transgenic animals (e.g. mice) that are capable, upon immunization, of producing a repertoire of human antibodies in the absence of endogenous immunoglobulin production (Jakobovits et al., Nature 362: 255-258 [1993]; Lonberg and Huszar, Int. Rev. Immunol.13: 65-93 [1995]; Fishwild et al., Nat. Biotechnol. 14: 845-851 [1996];Mendez et al., Nat. Genet. 15: 146-156 [1997]; Green, J. Immunol. Methods231: 11-23 [1999]; Tomizuka et a1., Proc. Natl. Acad. Sci. U5A 97:722727 [2000]; reviewed in Little et al., Immunol. Today 21: 364-370 [2000]). For example, it has been described that the homozygous deletion of the antibody heavy chain joining region (JH) gene in chimeric and germ-line mutant mice results in complete inhibition of endogenous antibody production (Jakobovits et al., Proc. Natl. Acad. Sci. V5A 90: 2551 -2555[1993]). Transfer of the human germ-line immunoglobulin gene array in such germ-line mutant mice results in the production of human antibodies upon antigenchallenge (Jakobovits et al., Nature 362: 255-258 [1993]). Mendez et al. (Nature Genetics 15: 146-156 [1997]) have generated a line of transgenic mice that, when challenged with an antigen, generates high affinity fully human antibodies. This was achieved by germ-line integration of megabase human heavy chain and light chain loci into mice with deletion into endogenous JH segment as described above. The XenoMouse II harbors 1,020 kb of human heavy chain locus containing approximately 66 VH genes, complete DH and JH regions and three different constant regions ('l, and By), and also harbors 800 kb of human K locus containing 32 VK genes, JK segments and CK genes. The antibodies produced in these mice closely resemble that seen in humans in all respects, including gene rearrangement, assembly, and repertoire. The

human antibodies are preferentially expressed over endogenous antibodies due to deletion in endogenous segment that prevents gene rearrangement in the murine locus. Such mice may be immunized with an antigen of particular interest.

Sera from such immunized animals may be screened for antibody reactivity against the initial antigen. Lymphocytes may be isolated from lymph nodes or spleen cells and may further be selected for B cells by selecting for CD138-negative and CDI9+cells. In one aspect, such B cell cultures (BCCs) may be fused to myeloma cells to generate hybridomas as detailed above.

In another aspect, such B cell cultures may be screened further for reactivity against the initial antigen, preferably. Such screening includes ELISA with the target/antigen protein, a competition assay with known antibodies that bind the antigen of interest and in vitro binding to transiently transfected CHO or other cells that express the target antigen.

The present invention is directed to compositions and methods for treating human patients with diseases mediated by stimulation of CD40 signaling on CD40-expressing cells. The methods involve treatment with an anti-CD40 antibody of the invention, or an antigen-binding fragment thereof, where administration of the antibody or antigen-binding fragment thereof promotes a positive therapeutic response within the patient undergoing this method of therapy. Anti-CD40 antibodies suitable for use in the methods of the invention specifically bind a human CD40 antigen expressed on the surface of a human cell and are free of significant agonist activity, but exhibit antagonist activity when bound to the CD40 antigen on a human CD40-expressing cell. These anti-CD40 antibodies and antigen-binding fragments thereof are referred to herein as antagonist anti-CD40 antibodies. Such antibodies include, but are not limited to, the fully human monoclonal antibodies 5.9 and 12.12 described below and monoclonal antibodies having the binding characteristics of monoclonal antibodies 5.9 and 12.12.

Antibodies that have the binding characteristics of monoclonal antibodies 5.9 and 12.12 include antibodies that competitively interfere with binding CD40 and/or bind the same epitopes as 5.9 and 12.12. One of skill could determine whether an antibody competitively interferes with 5.9 or 12.12 using standard methods.

When these antibodies bind CD40 displayed on the surface of human cells, such as human B cells, the antibodies are free of significant agonist activity; in some embodiments, their binding to CD40 displayed on the surface of human cells results in inhibition of proliferation and differentiation of these human cells. Thus, the antagonist anti-CD40 antibodies suitable for use in the methods of the invention include those monoclonal antibodies that can exhibit antagonist activity toward normal and malignant human cells expressing the cell-surface CD40 antigen.

In some embodiments, the anti-CD40 antibodies of the invention exhibit increased anti-tumor activity relative to the chimeric anti-CD20 monoclonal antibody IDEC-C2B8, where anti-tumor activity is assayed with equivalent amounts of these antibodies in a nude mouse xenograft tumor model using human lymphoma cell lines. IDEC-C2B8 (IDEC Pharmaceuticals Corp., San Diego, California; commercially available under the tradename Rituxan®, also referred to as rituximab) is a chimeric anti-CD20 monoclonal antibody containing human IgG1 and kappa constant regions with murine variable regions isolated from a murine anti-CD20 monoclonal antibody, IDEC-2B8 (Reff *et al.* (1994) *Blood* 83:435-445). Rituximab® is licensed for treatment of relapsed B cell low-grade or follicular non-Hodgkin's lymphoma (NHL). The discovery of antibodies with superior anti-tumor activity compared to Rituximab® could drastically improve methods of cancer therapy for B cell lymphomas, particularly B cell non-Hodgkin's lymphoma.

Suitable nude mouse xenograft tumor models include those using the human Burkitt's lymphoma cell lines known as Namalwa and Daudi. Preferred embodiments assay anti-tumor activity in a staged nude mouse xenograft tumor model using the Daudi human lymphoma cell line as described herein below in Example 17. A staged nude mouse xenograft tumor model using the Daudi lymphoma cell line is more effective at distinguishing the therapeutic efficacy of a given antibody than is an unstaged model, as in the staged model antibody dosing is initiated only after the tumor has reached a measurable size. In the unstaged model, antibody dosing is initiated generally within about 1 day of tumor inoculation and before a palpable tumor is present. The ability of an antibody to outperform Rituxan® (i.e., to exhibit increased anti-tumor activity) in a staged model is a strong indication that the antibody will be more therapeutically

effective than Rituxan®. Moreover, in the Daudi model, anti-CD20, the target for Rituxan® is expressed on the cell surface at a higher level than is CD40.

By "equivalent amount" of the anti-CD40 antibody of the invention and Rituxan® is intended the same mg dose is administered on a per weight basis. Thus, where the anti-CD40 antibody of the invention is dosed at 0.01 mg/kg body weight of the mouse used in the tumor model, Rituxan® is also dosed at 0.01 mg/kg body weight of the mouse. Similarly, where the anti-CD40antibody of the invention is dosed at 0.1, 1, or 10 mg/kg body weight of the mouse used in the tumor model, the Rituxan® is also dosed at 0.1, 1, or 10 mg/kg, respectively, of the body weight of the mouse.

When administered in the nude mouse xenograft tumor model, some antibodies of the invention result in significantly less tumor volume than an equivalent amount of Rituxan®. Thus, for example, the fully human monoclonal antibody 12.12 exhibits at least a 20% increase in anti-tumor activity relative to that observed with an equivalent dose of Rituxan when assayed in the staged nude mouse xenograft tumor model using the Daudi human lymphoma cell line in the manner described in Examples herein below, and can exhibit as much as a 50% to 60% increase in anti-tumor activity in this assay. This increased anti-tumor activity is reflected in the greater reduction in tumor volume observed with the anti-CD40 antibody of the invention when compared to the equivalent dose of Rituxan®. Thus, for example, depending upon the length of time after tumor inoculation, the monoclonal antibody 12.12 can exhibit a tumor volume that is about one-third to about one-half that observed for an equivalent dose of Rituxan®.

Another difference in antibody efficacy is to measure *in vitro* the concentration of antibody needed to obtain the maximum lysis of tumor cells *in vitro* in the presence of NK cells. For example, the anti-CD40 antibodies of the invention reach maximum lysis of Daudi cells at an EC50 of less than ½, and preferably ¼, and most preferably, 1/10 the concentration of Rituxan®.

In addition to the monoclonal antibody 12.12, other anti-CD40 antibodies that would share the characteristics of having significantly greater efficacy than equivalent amounts of Rituxan® in the assays described above include, but are not limited to: (1) the monoclonal antibody produced by the hybridoma cell line 12.12; (2) a monoclonal antibody comprising an amino acid sequence selected from the group consisting of the

sequence in Fig. 10A, the sequence in Figure 10B, and both the sequence in Fig. 10A and 10B; (3) a monoclonal antibody having an amino acid sequence encoded by a nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of the nucleotide sequence in Fig. 12A, the nucleotide sequence in Fig. 12B, and both the sequence in Fig. 12A and Fig. 12B; (4) a monoclonal antibody that binds to an epitope capable of binding the monoclonal antibody produced by the hybridoma cell line 12.12; (5) a monoclonal antibody that binds to an epitope comprising residues 82-87 of the amino acid sequence in Fig. 13B; (6) a monoclonal antibody that competes with the monoclonal antibody 12.12 in a competitive binding assay; and (7) a monoclonal antibody that is an antigen-binding fragment of the 12.12 monoclonal antibody or the foregoing monoclonal antibodies in preceding items (1)-(6), where the fragment retains the capability of specifically binding to the human CD40 antigen.

Antagonist Anti-CD40 Antibodies

The monoclonal antibodies 5.9 and 12.12 represent suitable antagonist anti-CD40 antibodies for use in the methods of the present invention. The 5.9 and 12.2 antibodies are fully human anti-CD40 monoclonal antibodies of the IgG_1 isotype produced from the hybridoma cell lines 131.2F8.5.9 (referred to herein as the cell line 5.9) and 153.8E2.D10.D6.12.12 (referred to herein as the cell line 12.12). These cell lines were created using splenocytes from immunized xenotypic mice containing the human IgG_1 heavy chain locus and the human K chain locus (Abgenix). The spleen cells were fused with the mouse myeloma SP2/0 cells (Sierra BioSource). The resulting hybridomas were sub-cloned several times to create the stable monoclonal cell lines 5.9 and 12.12. Other antibodies of the invention may be prepared similarly using mice transgenic for human immunoglobulin loci or by other methods known in the art and/or described herein.

The amino acid sequences of the variable regions of the 5.9 antibody, and the nucleotide and amino acid sequences of the variable regions of the 12.12 antibody, are disclosed. The amino acid sequences for the variable region for the light chain and heavy chain of the 5.9 mAb are set forth in Figs. 11A and 11B, respectively. The amino acid sequences for the variable region for the light chain and heavy chain for the 12.12 mAb are set forth in Figs. 10A and 10B, respectively. The nucleotide sequences encoding the

light chain and heavy chain for the 12.12 mAb are set forth in Figs. 12A and 12B, respectively. Further, hybridomas expressing 5.9 and 12.12 antibodies have been deposited with the ATCC with a patent deposit designation of PTA-5542 and PTA-5543 respectively.

In addition to antagonist activity, it is preferable that anti-CD40 antibodies of this invention have anther mechanism of action against a tumor cell. For example, native 5.9 and 12.12 antibodies have ADCC activity. Alternatively, the variable regions of the 5.9 and 12.12 antibodies can be expressed on another antibody isotype that has ADCC activity. It is also possible to conjugate native forms, recombinant forms, or antigen-biding fragments of 5.9 or 12.12 to a cytotoxic toxin.

The 5.9 and 12.12 monoclonal antibodies bind soluble CD40 in ELISA-type assays, prevent the binding of CD40-ligand to cell-surface CD40, and displace the pre-bound CD40-ligand, as determined by flow cytometric assays. Antibodies 5.9 and 12.12 compete with each other for binding to CD40 but not with 15B8, the anti-CD40 monoclonal antibody described in U.S. Provisional Application Serial No. 60/237,556, titled "*Human Anti-CD40 Antibodies*," filed October 2, 2000, and PCT International Application No. PCT/US01/30857, also titled "*Human Anti-CD40 Antibodies*," filed October 2, 2001 (Attorney Docket No. PP16092.003), both of which are herein incorporated by reference in their entirety. When tested *in vitro* for effects on proliferation of B cells from normal human subjects, 5.9 and 12.12 act as antagonistic anti-CD40 antibodies. Furthermore, 5.9 and 12.12 do not induce strong proliferation of human lymphocytes from normal subjects. These antibodies are able to kill CD40-expressing target cells by antibody dependent cellular cytotoxicity (ADCC). The binding affinity of 5.9 for human CD40 is 1.2×10^{-8} M and the binding affinity of 12.12 is 5×10^{-10} M, as determined by the Biacore™ assay.

Suitable antagonist anti-CD40 antibodies for use in the methods of the present invention exhibit a strong single-site binding affinity for the CD40 cell-surface antigen. The monoclonal antibodies of the invention exhibit a dissociation equilibrium constant (K_D) for CD40 of at least 10^{-5} M, at least 3×10^{-5} M, preferably at least 10^{-6} M to 10^{-7} M, more preferably at least 10^{-8} M to about 10^{-12} M, measured using a standard assay such as Biacore™. Biacore analysis is known in the art and details are provided in the

"BIAapplications handbook." Methods described in WO 01/27160 can be used to modulate the binding affinity.

By "CD40 antigen" is intended a glycosylated transmembrane peptide or any fragment thereof (GenBank Accession No. X60592; U.S. Patent Nos. 5,674,492 and 4,708,871; Stamenkovic *et al.* (1989) *EMBO* 8:1403; Clark (1990) *Tissue Antigens* 36:33; Barclay *et al.* (1997) *The Leucocyte Antigen Facts Book* (2d ed.; Academic Press, San Diego)). The CD40 receptor is displayed on the surface of a variety of cell types, as described elsewhere herein. By "displayed on the surface" and "expressed on the surface" is intended that all or a portion of the CD40 antigen is exposed to the exterior of the cell. The displayed or expressed CD40 antigen may be fully or partially glycosylated.

By "agonist activity" is intended that the substance functions as an agonist. An agonist combines with a receptor on a cell and initiates a reaction or activity that is similar to or the same as that initiated by the receptor's natural ligand. An agonist of CD40 induces any or all of, but not limited to, the following responses: B cell proliferation and differentiation, antibody production, intercellular adhesion, B cell memory generation, isotype switching, up-regulation of cell-surface expression of MHC Class II and CD80/86, and secretion of pro-inflammatory cytokines such as IL-8, IL-12, and TNF. By "antagonist activity" is intended that the substance functions as an antagonist. An antagonist of CD40 prevents or reduces induction of any of the responses induced by binding of the CD40 receptor to an agonist ligand, particularly CD40L. The antagonist may reduce induction of any one or more of the responses to agonist binding by 5%, 10%, 15%, 20%, 25%, 30%, 35%, preferably 40%, 45%, 50%, 55%, 60%, more preferably 70%, 80%, 85%, and most preferably 90%, 95%, 99%, or 100%. Methods for measuring anti-CD40 antibody and CD40-ligand binding specificity and antagonist activity are known to one of skill in the art and include, but are not limited to, standard competitive binding assays, assays for monitoring immunoglobulin secretion by B cells, B cell proliferation assays, Banchereau-Like-B cell proliferation assays, T cell helper assays for antibody production, co-stimulation of B cell proliferation assays, and assays for up-regulation of B cell activation markers. See, for example, such assays disclosed in WO 00/75348 and U.S. Patent No. 6,087,329, herein incorporated by reference.

By "significant" agonist activity is intended an agonist activity of at least 30%, 35%, 40%, 45%, 50%, 60%, 70%, 75%, 80%, 85%, 90%, 95%, or 100% greater than the agonist activity induced by a neutral substance or negative control as measured in an assay of a B cell response. A substance "free of significant agonist activity" would exhibit an agonist activity of not more than about 25% greater than the agonist activity induced by a neutral substance or negative control, preferably not more than about 20% greater, 15% greater, 10% greater, 5% greater, 1% greater, 0.5% greater, or even not more than about 0.1% greater than the agonist activity induced by a neutral substance or negative control as measured in an assay of a B cell response. The antagonist anti-CD40 antibodies useful in the methods of the present invention are free of significant agonist activity as noted above when bound to a CD40 antigen on a human cell. In one embodiment of the invention, the antagonist anti-CD40 antibody is free of significant agonist activity in one B cell response. In another embodiment of the invention, the antagonist anti-CD40 antibody is free of significant agonist activity in assays of more than one B cell response (e.g., proliferation and differentiation, or proliferation, differentiation, and antibody production).

As used herein "anti-CD40 antibody" encompasses any antibody that specifically recognizes the CD40 B cell surface antigen, including polyclonal antibodies, monoclonal antibodies, single-chain antibodies, and fragments thereof such as Fab, $F(ab')_2$, F_v, and other fragments which retain the antigen binding function of the parent anti-CD40 antibody. Of particular interest to the methods of the present invention are the binding properties exhibited by the 5.9 and 12.12 monoclonal antibodies described above.

Polyclonal sera may be prepared by conventional methods. In general, a solution containing the CD40 antigen is first used to immunize a suitable animal, preferably a mouse, rat, rabbit, or goat. Rabbits or goats are preferred for the preparation of polyclonal sera due to the volume of serum obtainable, and the availability of labeled anti-rabbit and anti-goat antibodies.

Polyclonal sera can be prepared in a transgenic animal, preferably a mouse bearing human immunoglobulin loci. In a preferred embodiment, Sf9 cells expressing CD40 are used as the immunogen. Immunization can also be performed by mixing or emulsifying the antigen-containing solution in saline, preferably in an adjuvant such as

Freund's complete adjuvant, and injecting the mixture or emulsion parenterally (generally subcutaneously or intramuscularly). A dose of 50-200 μg/injection is typically sufficient. Immunization is generally boosted 2-6 weeks later with one or more injections of the protein in saline, preferably using Freund's incomplete adjuvant. One may alternatively generate antibodies by *in vitro* immunization using methods known in the art, which for the purposes of this invention is considered equivalent to *in vivo* immunization. Polyclonal antisera are obtained by bleeding the immunized animal into a glass or plastic container, incubating the blood at 25°C for one hour, followed by incubating at 4°C for 2-18 hours. The serum is recovered by centrifugation (e.g., 1,000 x g for 10 minutes). About 20-50 ml per bleed may be obtained from rabbits.

Production of the Sf 9 (*Spodoptera frugiperda*) cells is disclosed in U.S. Patent No. 6,004,552, incorporated herein by reference. Briefly, sequences encoding human CD40 were recombined into a baculovirus using transfer vectors. The plasmids were co-transfected with wild-type baculovirus DNA into Sf 9 cells. Recombinant baculovirus-infected Sf 9 cells were identified and clonally purified.

Preferably the antibody is monoclonal in nature. By "monoclonal antibody" is intended an antibody obtained from a population of substantially homogeneous antibodies, i.e., the individual antibodies comprising the population are identical except for possible naturally occurring mutations that may be present in minor amounts. The term is not limited regarding the species or source of the antibody. The term encompasses whole immunoglobulins as well as fragments such as Fab, F(ab')2, Fv, and others which retain the antigen binding function of the antibody. Monoclonal antibodies are highly specific, being directed against a single antigenic site, i.e., the CD40 cell surface antigen in the present invention. Furthermore, in contrast to conventional (polyclonal) antibody preparations that typically include different antibodies directed against different determinants (epitopes), each monoclonal antibody is directed against a single determinant on the antigen. The modifier "monoclonal" indicates the character of the antibody as being obtained from a substantially homogeneous population of antibodies, and is not to be construed as requiring production of the antibody by any particular method. For example, the monoclonal antibodies to be used in accordance with the present invention may be made by the hybridoma method first described by

Kohler *et al.* (1975) *Nature* 256:495, or may be made by recombinant DNA methods (see, *e.g.*, U.S. Patent No. 4,816,567). The "monoclonal antibodies" may also be isolated from phage antibody libraries using the techniques described in, for example, Clackson *et al.* (1991) *Nature* 352:624-628; Marks *et al.* (1991) *J. Mol. Biol.* 222:581-597; and U.S. Patent No. 5,514,548.

By "epitope" is intended the part of an antigenic molecule to which an antibody is produced and to which the antibody will bind. Epitopes can comprise linear amino acid residues (i.e., residues within the epitope are arranged sequentially one after another in a linear fashion), nonlinear amino acid residues (referred to herein as "nonlinear epitopes"; these epitopes are not arranged sequentially), or both linear and nonlinear amino acid residues.

Monoclonal antibodies can be prepared using the method of Kohler *et al.* (1975) *Nature* 256:495-496, or a modification thereof. Typically, a mouse is immunized with a solution containing an antigen. Immunization can be performed by mixing or emulsifying the antigen-containing solution in saline, preferably in an adjuvant such as Freund's complete adjuvant, and injecting the mixture or emulsion parenterally. Any method of immunization known in the art may be used to obtain the monoclonal antibodies of the invention. After immunization of the animal, the spleen (and optionally, several large lymph nodes) are removed and dissociated into single cells. The spleen cells may be screened by applying a cell suspension to a plate or well coated with the antigen of interest. The B cells expressing membrane bound immunoglobulin specific for the antigen bind to the plate and are not rinsed away. Resulting B cells, or all dissociated spleen cells, are then induced to fuse with myeloma cells to form hybridomas, and are cultured in a selective medium. The resulting cells are plated by serial dilution and are assayed for the production of antibodies that specifically bind the antigen of interest (and that do not bind to unrelated antigens). The selected monoclonal antibody (mAb)-secreting hybridomas are then cultured either *in vitro* (e.g., in tissue culture bottles or hollow fiber reactors), or *in vivo* (as ascites in mice).

As an alternative to the use of hybridomas, antibody can be produced in a cell line such as a CHO cell line, as disclosed in U.S. Patent Nos. 5,545,403; 5,545,405; and 5,998,144; incorporated herein by reference. Briefly the cell line is transfected with

vectors capable of expressing a light chain and a heavy chain, respectively. By transfecting the two proteins on separate vectors, chimeric antibodies can be produced. Another advantage is the correct glycosylation of the antibody.

Monoclonal antibodies to CD40 are known in the art. See, for example, the sections dedicated to B-cell antigen in McMichael, ed. (1987; 1989) *Leukocyte Typing III and IV* (Oxford University Press, New York); U.S. Patent Nos. 5,674,492; 5,874,082; 5,677,165; 6,056,959; WO 00/63395; International Publication Nos. WO 02/28905 and WO 02/28904; Gordon *et al.* (1988) *J. Immunol.* 140:1425; Valle *et al.* (1989) *Eur. J. Immunol.* 19:1463; Clark *et al.* (1986) *PNAS* 83:4494; Paulie *et al.* (1989) *J. Immunol.* 142:590; Gordon *et al.* (1987) *Eur. J. Immunol.* 17:1535; Jabara *et al.* (1990) *J. Exp. Med.* 172:1861; Zhang *et al.* (1991) *J. Immunol.* 146:1836; Gascan *et al.* (1991) *J. Immunol.* 147:8; Banchereau *et al.* (1991) *Clin. Immunol. Spectrum* 3:8; and Banchereau *et al.* (1991) *Science* 251:70; all of which are herein incorporated by reference. Of particular interest to the present invention are the antagonist anti-CD40 antibodies disclosed herein that share the binding characteristics of the monoclonal antibodies 5.9 and 12.12 described above.

The term "CD40-antigen epitope" as used herein refers to a molecule that is capable of immunoreactivity with the anti-CD40 monoclonal antibodies of this invention, excluding the CD40 antigen itself. CD40-antigen epitopes may comprise proteins, protein fragments, peptides, carbohydrates, lipids, and other molecules, but for the purposes of the present invention are most commonly proteins, short oligopeptides, oligopeptide mimics (i e, organic compounds which mimic the antibody binding properties of the CD40 antigen), or combinations thereof. Suitable oligopeptide mimics are described, inter alia, in PCT application US 591/04282.

Additionally, the term "anti-CD40 antibody" as used herein encompasses chimeric anti-CD40 antibodies; such chimeric anti-CD40 antibodies for use in the methods of the invention have the binding characteristics of the 5.9 and 12.12 monoclonal antibodies described herein. By "chimeric" antibodies is intended antibodies that are most preferably derived using recombinant deoxyribonucleic acid techniques and which comprise both human (including immunologically "related" species, e.g., chimpanzee) and non-human components. Thus, the constant region of the chimeric

antibody is most preferably substantially identical to the constant region of a natural human antibody; the variable region of the chimeric antibody is most preferably derived from a non-human source and has the desired antigenic specificity to the CD40 cell-surface antigen. The non-human source can be any vertebrate source that can be used to generate antibodies to a human CD40 cell-surface antigen or material comprising a human CD40 cell-surface antigen. Such non-human sources include, but are not limited to, rodents (e.g., rabbit, rat, mouse, etc.; see, for example, U.S. Patent No. 4,816,567, herein incorporated by reference) and non-human primates (e.g., Old World Monkey, Ape, etc.; see, for example, U.S. Patent Nos. 5,750,105 and 5,756,096; herein incorporated by reference). As used herein, the phrase "immunologically active" when used in reference to chimeric anti-CD40 antibodies means a chimeric antibody that binds human CD40.

Chimeric and humanized anti-CD40 antibodies are also encompassed by the term anti-CD40 antibody as used herein. Chimeric antibodies comprise segments of antibodies derived from different species. Rituxan® is an example of a chimeric antibody with a murine variable region and a human constant region.

By "humanized" is intended forms of anti-CD40 antibodies that contain minimal sequence derived from non-human immunoglobulin sequences. For the most part, humanized antibodies are human immunoglobulins (recipient antibody) in which residues from a hypervariable region (also known as complementarity determining region or CDR) of the recipient are replaced by residues from a hypervariable region of a non-human species (donor antibody) such as mouse, rat, rabbit, or nonhuman primate having the desired specificity, affinity, and capacity. The phrase "complementarity determining region" refers to amino acid sequences which together define the binding affinity and specificity of the natural Fv region of a native immunoglobulin binding site. See, e.g., Chothia *et al* (1987) *J. Mol. Biol.* 196:901-917; Kabat *et al* (1991) U. S. Dept. of Health and Human Services, NIH Publication No. 91-3242). The phrase "constant region" refers to the portion of the antibody molecule that confers effector functions. In previous work directed towards producing non-immunogenic antibodies for use in therapy of human disease, mouse constant regions were substituted by human constant regions. The constant regions of the subject humanized antibodies were derived from human

immunoglobulins. However, these humanized antibodies still elicited an unwanted and potentially dangerous immune response in humans and there was a loss of affinity. Humanized anti-CD40 antibodies for use in the methods of the present invention have binding characteristics similar to those exhibited by the 5.9 and 12.12 monoclonal antibodies described herein.

Humanization can be essentially performed following the method of Winter and co-workers (Jones *et al.* (1986) *Nature* 321:522-525; Riechmann *et al.* (1988) *Nature* 332:323-327; Verhoeyen *et al.* (1988) *Science* 239:1534-1536), by substituting rodent or mutant rodent CDRs or CDR sequences for the corresponding sequences of a human antibody. See also U.S. Patent Nos. 5,225,539; 5,585,089; 5,693,761; 5,693,762; 5,859,205; herein incorporated by reference. In some instances, residues within the framework regions of one or more variable regions of the human immunoglobulin are replaced by corresponding non-human residues (see, for example, U.S. Patent Nos. 5,585,089; 5,693,761; 5,693,762; and 6,180,370). Furthermore, humanized antibodies may comprise residues that are not found in the recipient antibody or in the donor antibody. These modifications are made to further refine antibody performance (e.g., to obtain desired affinity). In general, the humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the hypervariable regions correspond to those of a non-human immunoglobulin and all or substantially all of the framework regions are those of a human immunoglobulin sequence. The humanized antibody optionally also will comprise at least a portion of an immunoglobulin constant region (Fc), typically that of a human immunoglobulin. For further details see Jones *et al.* (1986) *Nature* 331:522-525; Riechmann *et al.* (1988) *Nature* 332:323-329; and Presta (1992) *Curr. Op. Struct. Biol.* 2:593-596; herein incorporated by reference. Accordingly, such "humanized" antibodies may include antibodies wherein substantially less than an intact human variable domain has been substituted by the corresponding sequence from a non-human species. In practice, humanized antibodies are typically human antibodies in which some CDR residues and possibly some framework residues are substituted by residues from analogous sites in rodent antibodies. See, for example, U.S. Patent Nos. 5,225,539; 5,585,089; 5,693,761; 5,693,762; 5,859,205. See also U.S. Patent No. 6,180,370, and International Publication

No. WO 01/27160, where humanized antibodies and techniques for producing humanized antibodies having improved affinity for a predetermined antigen are disclosed.

Also encompassed by the term anti-CD40 antibodies are xenogeneic or modified anti-CD40 antibodies produced in a non-human mammalian host, more particularly a transgenic mouse, characterized by inactivated endogenous immunoglobulin (Ig) loci. In such transgenic animals, competent endogenous genes for the expression of light and heavy subunits of host immunoglobulins are rendered non-functional and substituted with the analogous human immunoglobulin loci. These transgenic animals produce human antibodies in the substantial absence of light or heavy host immunoglobulin subunits. See, for example, U.S. Patent Nos. 5,877,397 and 5,939,598, herein incorporated by reference.

Preferably, fully human antibodies to CD40 are obtained by immunizing transgenic mice. One such mouse is referred to as a Xenomouse, and is disclosed in U.S. Patent Nos. 6,075,181, 6,091,001, and 6,114,598, all of which are incorporated herein by reference. To produce the antibodies disclosed herein, mice transgenic for the human Ig G_1 heavy chain locus and the human K light chain locus were immunized with Sf 9 cells expressing human CD40. Mice can also be transgenic for other isotypes. Fully human antibodies useful in the methods of the present invention are characterized by binding properties similar to those exhibited by the 5.9 and 12.12 monoclonal antibodies disclosed herein.

Fragments of the anti-CD40 antibodies are suitable for use in the methods of the invention so long as they retain the desired affinity of the full-length antibody. Thus, a fragment of an anti-CD40 antibody will retain the ability to bind to the CD40 B cell surface antigen. Such fragments are characterized by properties similar to the corresponding full-length antagonist anti-CD40 antibody, that is, the fragments will specifically bind a human CD40 antigen expressed on the surface of a human cell, and are free of significant agonist activity but exhibit antagonist activity when bound to a CD40 antigen on a human CD40-expressing cell. Such fragments are referred to herein as "antigen-binding" fragments.

Suitable antigen-binding fragments of an antibody comprise a portion of a full-length antibody, generally the antigen-binding or variable region thereof. Examples of

antibody fragments include, but are not limited to, Fab, $F(ab')_2$, and Fv fragments and single-chain antibody molecules. By "Fab" is intended a monovalent antigen-binding fragment of an immunoglobulin that is composed of the light chain and part of the heavy chain. By $F(ab')_2$ is intended a bivalent antigen-binding fragment of an immunoglobulin that contains both light chains and part of both heavy chains. By "single-chain Fv" or "sFv" antibody fragments is intended fragments comprising the V_H and V_L domains of an antibody, wherein these domains are present in a single polypeptide chain. See, for example, U.S. Patent Nos. 4,946,778, 5,260,203, 5,455,030, and 5,856,456, herein incorporated by reference. Generally, the Fv polypeptide further comprises a polypeptide linker between the V_H and V_L domains that enables the sFv to form the desired structure for antigen binding. For a review of sFv see Pluckthun (1994) in *The Pharmacology of Monoclonal Antibodies*, Vol. 113, ed. Rosenburg and Moore (Springer-Verlag, New York), pp. 269-315.

Antibodies or antibody fragments can be isolated from antibody phage libraries generated using the techniques described in, for example, McCafferty *et al.* (1990) *Nature* 348:552-554 (1990) and U.S. Patent No. 5,514,548. Clackson *et al.* (1991) *Nature* 352:624-628 and Marks *et al.* (1991) *J. Mol. Biol.* 222:581-597 describe the isolation of murine and human antibodies, respectively, using phage libraries. Subsequent publications describe the production of high affinity (nM range) human antibodies by chain shuffling (Marks *et al.* (1992) *Bio/Technology* 10:779-783), as well as combinatorial infection and *in vivo* recombination as a strategy for constructing very large phage libraries (Waterhouse *et al.* (1993) *Nucleic. Acids Res.* 21:2265-2266). Thus, these techniques are viable alternatives to traditional monoclonal antibody hybridoma techniques for isolation of monoclonal antibodies.

Various techniques have been developed for the production of antibody fragments. Traditionally, these fragments were derived *via* proteolytic digestion of intact antibodies (see, e.g., Morimoto *et al.* (1992) *Journal of Biochemical and Biophysical Methods* 24:107-117 (1992) and Brennan *et al.* (1985) *Science* 229:81). However, these fragments can now be produced directly by recombinant host cells. For example, the antibody fragments can be isolated from the antibody phage libraries discussed above. Alternatively, Fab'-SH fragments can be directly recovered from *E. coli* and chemically

coupled to form $F(ab')_2$ fragments (Carter *et al.* (1992) *Bio/Technology* 10:163-167). According to another approach, $F(ab')_2$ fragments can be isolated directly from recombinant host cell culture. Other techniques for the production of antibody fragments will be apparent to the skilled practitioner.

Antagonist anti-CD40 antibodies useful in the methods of the present invention include the 5.9 and 12.12 monoclonal antibodies disclosed herein as well as antibodies differing from this antibody but retaining the CDRs; and antibodies with one or more amino acid addition(s), deletion(s), or substitution(s), wherein the antagonist activity is measured by inhibition of B-cell proliferation and/or differentiation. The invention also encompasses de-immunized antagonist anti-CD40 antibodies, which can be produced as described in, for example, International Publication Nos. WO 98/52976 and WO 0034317; herein incorporated by reference. In this manner, residues within the antagonist anti-CD40 antibodies of the invention are modified so as to render the antibodies non- or less immunogenic to humans while retaining their antagonist activity toward human CD40-expressing cells, wherein such activity is measured by assays noted elsewhere herein. Also included within the scope of the claims are fusion proteins comprising an antagonist anti-CD40 antibody of the invention, or a fragment thereof, which fusion proteins can be synthesized or expressed from corresponding polynucleotide vectors, as is known in the art. Such fusion proteins are described with reference to conjugation of antibodies as noted below.

The antibodies of the present invention can have sequence variations produced using methods described in, for example, Patent Publication Nos. EP 0 983 303 A1, WO 00/34317, and WO 98/52976, incorporated herein by reference. For example, it has been shown that sequences within the CDR can cause an antibody to bind to MHC Class II and trigger an unwanted helper T-cell response. A conservative substitution can allow the antibody to retain binding activity yet lose its ability to trigger an unwanted T-cell response. Any such conservative or non-conservative substitutions can be made using art-recognized methods, such as those noted elsewhere herein, and the resulting antibodies will fall within the scope of the invention. The variant antibodies can be routinely tested for antagonist activity, affinity, and specificity using methods described herein.

An antibody produced by any of the methods described above, or any other method not disclosed herein, will fall within the scope of the invention if it possesses at least one of the following biological activities: inhibition of immunoglobulin secretion by normal human peripheral B cells stimulated by T cells; inhibition of proliferation of normal human peripheral B cells stimulated by Jurkat T cells; inhibition of proliferation of normal human peripheral B cells stimulated by CD40L-expressing cells or suoluble CD40; and inhibition of proliferation of human malignant B cells as noted below. These assays can be performed as described in the Examples herein. See also the assays described in Schultze *et al.* (1998) *Proc. Natl. Acad. Sci. USA* 92:8200-8204; Denton *et al.* (1998) *Pediatr. Transplant.* 2:6-15; Evans *et al.* (2000) *J. Immunol.* 164:688-697; Noelle (1998) *Agents Actions Suppl.* 49:17-22; Lederman *et al.* (1996) *Curr. Opin. Hematol.* 3:77-86; Coligan *et al.* (1991) *Current Protocols in Immunology* 13:12; Kwekkeboom *et al.* (1993) *Immunology* 79:439-444; and U.S. Patent Nos. 5,674,492 and 5,847,082; herein incorporated by reference.

A representative assay to detect antagonistic anti-CD40 antibodies specific to the CD40-antigen epitopes identified herein is a "competitive binding assay". Competitive binding assays are serological assays in which unknowns are detected and quantitated by their ability to inhibit the binding of a labeled known ligand to its specific antibody. This is also referred to as a competitive inhibition assay. In a representative competitive binding assay, labeled CD40 polypeptide is precipitated by candidate antibodies in a sample, for example, in combination with monoclonal antibodies raised against one or more epitopes of the monoclonal antibodies of the invention. Anti-CD40 antibodies that specifically react with an epitope of interest can be identified by screening a series of antibodies prepared against a CD40 protein or fragment of the protein comprising the particular epitope of the CD40 protein of interest. For example, for human CD40, epitopes of interest include epitopes comprising linear and/or nonlinear amino acid residues of human CD40 (GenBank Accession No. NP_690593) set forth in Fig. 13B (encoded by the sequence set forth in Fig. 13A). Alternatively, competitive binding assays with previously identified suitable antagonist anti-CD40 antibodies could be used to select monoclonal antibodies comparable to the previously identified antibodies.

Antibodies employed in such immunoassays may be labeled or unlabeled. Unlabeled antibodies may be employed in agglutination; labeled antibodies may be employed in a wide variety of assays, employing a wide variety of labels. Detection of the formation of an antibody-antigen complex between an anti-CD40 antibody and an epitope of interest can be facilitated by attaching a detectable substance to the antibody. Suitable detection means include the use of labels such as radionuclides, enzymes, coenzymes, fluorescers, chemiluminescers, chromogens, enzyme substrates or co-factors, enzyme inhibitors, prosthetic group complexes, free radicals, particles, dyes, and the like. Examples of suitable enzymes include horseradish peroxidase, alkaline phosphatase, β-galactosidase, or acetylcholinesterase; examples of suitable prosthetic group complexes include streptavidin/biotin and avidin/biotin; examples of suitable fluorescent materials include umbelliferone, fluorescein, fluorescein isothiocyanate, rhodamine, dichlorotriazinylamine fluorescein, dansyl chloride or phycoerythrin; an example of a luminescent material is luminol; examples of bioluminescent materials include luciferase, luciferin, and aequorin; and examples of suitable radioactive material include ^{125}I, ^{131}I, ^{35}S, or ^{3}H. Such labeled reagents may be used in a variety of well-known assays, such as radioimmunoassays, enzyme immunoassays, e.g., ELISA, fluorescent immunoassays, and the like. See for example, U.S. Patent Nos. 3,766,162; 3,791,932; 3,817,837; and 4,233,402.

Any of the previously described antagonist anti-CD40 antibodies or antibody fragments thereof may be conjugated prior to use in the methods of the present invention. Methods for producing conjugated antibodies are known in the art. Thus, the anti-CD40 antibody may be labeled using an indirect labeling or indirect labeling approach. By "indirect labeling" or "indirect labeling approach" is intended that a chelating agent is covalently attached to an antibody and at least one radionuclide is inserted into the chelating agent. See, for example, the chelating agents and radionuclides described in Srivagtava and Mease (1991) *Nucl. Med. Bio.* 18:589-603, herein incorporated by reference. Suitable labels include fluorophores, chromophores, radioactive atoms (particularly ^{32}P and ^{125}I), electron-dense reagents, enzymes, and ligands having specific binding partners. Enzymes are typically detected by their activity. For example, horseradish peroxidase is usually detected by its ability to convert 3,3',5,5'-

tetramethylbenzidine (TMB) to a blue pigment, quantifiable with a spectrophotometer. "Specific binding partner" refers to a protein capable of binding a ligand molecule with high specificity, as for example in the case of an antigen and a monoclonal antibody specific therefore. Other specific binding partners include biotin and avidin or streptavidin, Ig G and protein A, and the numerous receptor-ligand couples known in the art. It should be understood that the above description is not meant to categorize the various labels into distinct classes, as the same label may serve in several different modes. For example, ^{125}I may serve as a radioactive label or as an electron-dense reagent. HRP may serve as enzyme or as antigen for a mAb. Further, one may combine various labels for desired effect. For example, mAbs and avidin also require labels in the practice of this invention: thus, one might label a mAb with biotin, and detect its presence with avidin labeled with ^{125}I, or with an anti-biotin mAb labeled with HRP. Other permutations and possibilities will be readily apparent to those of ordinary skill in the art, and are considered as equivalents within the scope of the instant invention.

Alternatively, the anti-CD40 antibody may be labeled using "direct labeling" or a "direct labeling approach," where a radionuclide is covalently attached directly to an antibody (typically via an amino acid residue). Preferred radionuclides are provided in Srivagtava and Mease (1991) *supra*. The indirect labeling approach is particularly preferred. See also, for example, International Publication Nos. WO 00/52031 and WO 00/52473, where a linker is used to attach a radioactive label to antibodies; and the labeled forms of anti-CD40 antibodies described in U.S. Patent No. 6,015,542; herein incorporated by reference.

Further, an antibody (or fragment thereof) may be conjugated to a therapeutic moiety such as a cytotoxin, a therapeutic agent, or a radioactive metal ion. A cytotoxin or cytotoxic agent includes any agent that is detrimental to cells. Examples include taxol, cytochalasin B, gramicidin D, ethidium bromide, emetine, mitomycin, etoposide, tenoposide, vincristine, vinblastine, colchicin, doxorubicin, daunorubicin, dihydroxy anthracin dione, mitoxantrone, mithramycin, actinomycin D, 1-dehydrotestosterone, glucocorticoids, procaine, tetracaine, lidocaine, propranolol, and puromycin and analogs or homologs thereof. Therapeutic agents include, but are not limited to, antimetabolites (e.g., methotrexate, 6-mercaptopurine, 6-thioguanine, cytarabine, 5-fluorouracil

decarbazine), alkylating agents (e.g., mechlorethamine, thioepa chlorambucil, melphalan, carmustine (BSNU) and lomustine (CCNU), cyclothosphamide, busulfan, dibromomannitol, streptozotocin, mitomycin C, and cis-dichlorodiamine platinum (II) (DDP) cisplatin), anthracyclines (e.g., daunorubicin (formerly daunomycin) and doxorubicin), antibiotics (e.g., dactinomycin (formerly actinomycin), bleomycin, mithramycin, and anthramycin (AMC)), and anti-mitotic agents (e.g., vincristine and vinblastine). The conjugates of the invention can be used for modifying a given biological response; the drug moiety is not to be construed as limited to classical chemical therapeutic agents. For example, the drug moiety may be a protein or polypeptide possessing a desired biological activity. Such proteins may include, for example, a toxin such as abrin, ricin A, pseudomonas exotoxin, or diphtheria toxin; a protein such as tumor necrosis factor, interferon-alpha, interferon-beta, nerve growth factor, platelet derived growth factor, tissue plasminogen activator; or, biological response modifiers such as, for example, lymphokines, interleukin-1 ("IL-1"), interleukin-2 ("IL-2"), interleukin-6 ("IL-6"), granulocyte macrophase colony stimulating factor ("GM-CSF"), granulocyte colony stimulating factor ("G-CSF"), or other growth factors.

Techniques for conjugating such therapeutic moiety to antibodies are well known. See, for example, Arnon *et al.* (1985) "Monoclonal Antibodies for Immunotargeting of Drugs in Cancer Therapy," in *Monoclonal Antibodies and Cancer Therapy*, ed. Reisfeld *et al.* (Alan R. Liss, Inc.), pp. 243-256; ed. Hellstrom *et al.* (1987) "Antibodies for Drug Delivery," in *Controlled Drug Delivery*, ed. Robinson *et al.* (2d ed; Marcel Dekker, Inc.), pp. 623-653; Thorpe (1985) "Antibody Carriers of Cytotoxic Agents in Cancer Therapy: A Review," in *Monoclonal Antibodies '84: Biological and Clinical Applications*, ed. Pinchera *et al.* pp. 475-506 (Editrice Kurtis, Milano, Italy, 1985); "Analysis, Results, and Future Prospective of the Therapeutic Use of Radiolabeled Antibody in Cancer Therapy," in *Monoclonal Antibodies for Cancer Detection and Therapy*, ed. Baldwin *et al.* (Academic Press, New York, 1985), pp. 303-316; and Thorpe *et al.* (1982) *Immunol. Rev.* 62:119-158.

Alternatively, an antibody can be conjugated to a second antibody to form an antibody heteroconjugate as described in U.S. Patent No. 4,676,980. In addition, linkers

may be used between the labels and the antibodies of the invention (see U.S. Patent No. 4,831,175). Antibodies or, antigen-binding fragments thereof may be directly labeled with radioactive iodine, indium, yttrium, or other radioactive particle known in the art (U.S. Patent No. 5,595,721). Treatment may consist of a combination of treatment with conjugated and nonconjugated antibodies administered simultaneously or subsequently (WO 00/52031 and WO 00/52473).

Variants of Antagonist Anti-CD40 Antibodies

Suitable biologically active variants of the antagonist anti-CD40 antibodies can be used in the methods of the present invention. Such variants will retain the desired binding properties of the parent antagonist anti-CD40 antibody. Methods for making antibody variants are generally available in the art.

For example, amino acid sequence variants of an antagonist anti-CD40 antibody, for example, the 5.9 or 12.12 monoclonal antibody described herein, can be prepared by mutations in the cloned DNA sequence encoding the antibody of interest. Methods for mutagenesis and nucleotide sequence alterations are well known in the art. See, for example, Walker and Gaastra, eds. (1983) Techniques in Molecular Biology (MacMillan Publishing Company, New York); Kunkel (1985) *Proc. Natl. Acad. Sci. USA* 82:488-492; Kunkel *et al.* (1987) *Methods Enzymol.* 154:367-382; Sambrook *et al.* (1989) Molecular Cloning: A Laboratory Manual (Cold Spring Harbor, New York); U.S. Patent No. 4,873,192; and the references cited therein; herein incorporated by reference. Guidance as to appropriate amino acid substitutions that do not affect biological activity of the polypeptide of interest may be found in the model of Dayhoff *et al.* (1978) in *Atlas of Protein Sequence and Structure* (Natl. Biomed. Res. Found., Washington, D.C.), herein incorporated by reference. Conservative substitutions, such as exchanging one amino acid with another having similar properties, may be preferred. Examples of conservative substitutions include, but are not limited to, Gly⇔Ala, Val⇔Ile⇔Leu, Asp⇔Glu, Lys⇔Arg, Asn⇔Gln, and Phe⇔Trp⇔Tyr.

In constructing variants of the antagonist anti-CD40 antibody polypeptide of interest, modifications are made such that variants continue to possess the desired activity, i.e., similar binding affinity and are capable of specifically binding to a human

CD40 antigen expressed on the surface of a human cell, and being free of significant agonist activity but exhibiting antagonist activity when bound to a CD40 antigen on a human CD40-expressing cell. Obviously, any mutations made in the DNA encoding the variant polypeptide must not place the sequence out of reading frame and preferably will not create complementary regions that could produce secondary mRNA structure. See EP Patent Application Publication No. 75,444.

Preferably, variants of a reference antagonist anti-CD40 antibody have amino acid sequences that have at least 70% or 75% sequence identity, preferably at least 80% or 85% sequence identity, more preferably at least 90%, 91%, 92%, 93%, 94% or 95% sequence identity to the amino acid sequence for the reference antagonist anti-CD40 antibody molecule, for example, the 5.9 or 12.12 monoclonal antibody described herein, or to a shorter portion of the reference antibody molecule. More preferably, the molecules share at least 96%, 97%, 98% or 99% sequence identity. For purposes of the present invention, percent sequence identity is determined using the Smith-Waterman homology search algorithm using an affine gap search with a gap open penalty of 12 and a gap extension penalty of 2, BLOSUM matrix of 62. The Smith-Waterman homology search algorithm is taught in Smith and Waterman (1981) *Adv. Appl. Math.* 2:482-489. A variant may, for example, differ from the reference antagonist anti-CD40 antibody by as few as 1 to 15 amino acid residues, as few as 1 to 10 amino acid residues, such as 6-10, as few as 5, as few as 4, 3, 2, or even 1 amino acid residue.

With respect to optimal alignment of two amino acid sequences, the contiguous segment of the variant amino acid sequence may have additional amino acid residues or deleted amino acid residues with respect to the reference amino acid sequence. The contiguous segment used for comparison to the reference amino acid sequence will include at least 20 contiguous amino acid residues, and may be 30, 40, 50, or more amino acid residues. Corrections for sequence identity associated with conservative residue substitutions or gaps can be made (see Smith-Waterman homology search algorithm).

The precise chemical structure of a polypeptide capable of specifically binding CD40 and retaining antagonist activity, particularly when bound to CD40 antigen on malignant B cells, depends on a number of factors. As ionizable amino and carboxyl groups are present in the molecule, a particular polypeptide may be obtained as an acidic

or basic salt, or in neutral form. All such preparations that retain their biological activity when placed in suitable environmental conditions are included in the definition of antagonist anti-CD40 antibodies as used herein. Further, the primary amino acid sequence of the polypeptide may be augmented by derivatization using sugar moieties (glycosylation) or by other supplementary molecules such as lipids, phosphate, acetyl groups and the like. It may also be augmented by conjugation with saccharides. Certain aspects of such augmentation are accomplished through post-translational processing systems of the producing host; other such modifications may be introduced *in vitro*. In any event, such modifications are included in the definition of an anti-CD40 antibody used herein so long as the antagonist properties of the anti-CD40 antibody are not destroyed. It is expected that such modifications may quantitatively or qualitatively affect the activity, either by enhancing or diminishing the activity of the polypeptide, in the various assays. Further, individual amino acid residues in the chain may be modified by oxidation, reduction, or other derivatization, and the polypeptide may be cleaved to obtain fragments that retain activity. Such alterations that do not destroy antagonist activity do not remove the polypeptide sequence from the definition of anti-CD40 antibodies of interest as used herein.

The art provides substantial guidance regarding the preparation and use of polypeptide variants. In preparing the anti-CD40 antibody variants, one of skill in the art can readily determine which modifications to the native protein nucleotide or amino acid sequence will result in a variant that is suitable for use as a therapeutically active component of a pharmaceutical composition used in the methods of the present invention.

Methods of Therapy Using the Antagonist Anti-CD40 Antibodies of the Invention

Methods of the invention are directed to the use of antagonist anti-CD40 antibodies to treat patients having a disease mediated by stimulation of CD40 signaling on CD40-expressing cells. By "CD40-expressing cell" is intended normal and malignant B cells. By "malignant" B cell is intended any neoplastic B cell, including but not limited to B cells derived from lymphomas including low-, intermediate-, and high-grade B cell lymphomas, immunoblastic lymphomas, non-Hodgkin's lymphomas, Hodgkin's disease, Epstein-Barr Virus (EBV) induced lymphomas, and AIDS-related lymphomas,

as well as B cell acute lymphoblastic leukemias, myelomas, chronic lymphocytic leukemias, acute myeloblastic leukemias, and the like.

"Treatment" is herein defined as the application or administration of an antagonist anti-CD40 antibody or antigen-binding fragment thereof to a patient, or application or administration of an antagonist anti-CD40 antibody or fragment thereof to an isolated tissue or cell line from a patient, where the patient has a disease, a symptom of a disease, or a predisposition toward a disease, where the purpose is to cure, heal, alleviate, relieve, alter, remedy, ameliorate, improve, or affect the disease, the symptoms of the disease, or the predisposition toward the disease. By "treatment" is also intended the application or administration of a pharmaceutical composition comprising the antagonist anti-CD40 antibodies or fragments thereof to a patient, or application or administration of a pharmaceutical composition comprising the anti-CD40 antibodies or fragments thereof to an isolated tissue or cell line from a patient, who has a disease, a symptom of a disease, or a predisposition toward a disease, where the purpose is to cure, heal, alleviate, relieve, alter, remedy, ameliorate, improve, or affect the disease, the symptoms of the disease, or the predisposition toward the disease.

By "anti-tumor activity" is intended a reduction in the rate of malignant CD40-expressing cell proliferation or accumulation, and hence a decline in growth rate of an existing tumor or in a tumor that arises during therapy, and/or destruction of existing neoplastic (tumor) cells or newly formed neoplastic cells, and hence a decrease in the overall size of a tumor during therapy. Therapy with at least one anti-CD40 antibody (or antigen-binding fragment thereof) causes a physiological response that is beneficial with respect to treatment of disease states associated with stimulation of CD40 signaling on CD40-expressing cells in a human.

The methods of the invention find use in the treatment of non-Hodgkin's lymphomas related to abnormal, uncontrollable B cell proliferation or accumulation. For purposes of the present invention, such lymphomas will be referred to according to the *Working Formulation* classification scheme, that is those B cell lymphomas categorized as low grade, intermediate grade, and high grade (see "The Non-Hodgkin's Lymphoma Pathologic Classification Project," *Cancer* 49(1982):2112-2135). Thus, low-grade B cell lymphomas include small lymphocytic, follicular small-cleaved cell, and follicular mixed

small-cleaved and large cell lymphomas; intermediate-grade lymphomas include follicular large cell, diffuse small cleaved cell, diffuse mixed small and large cell, and diffuse large cell lymphomas; and high-grade lymphomas include large cell immunoblastic, lymphoblastic, and small non-cleaved cell lymphomas of the Burkitt's and non-Burkitt's type.

It is recognized that the methods of the invention are useful in the therapeutic treatment of B cell lymphomas that are classified according to the Revised European and American Lymphoma Classification (REAL) system. Such B cell lymphomas include, but are not limited to, lymphomas classified as precursor B cell neoplasms, such as B lymphoblastic leukemia/lymphoma; peripheral B cell neoplasms, including B cell chronic lymphocytic leukemia/small lymphocytic lymphoma, lymphoplasmacytoid lymphoma/immunocytoma, mantle cell lymphoma (MCL), follicle center lymphoma (follicular) (including diffuse small cell, diffuse mixed small and large cell, and diffuse large cell lymphomas), marginal zone B cell lymphoma (including extranodal, nodal, and splenic types), hairy cell leukemia, plasmacytoma/ myeloma, diffuse large cell B cell lymphoma of the subtype primary mediastinal (thymic), Burkitt's lymphoma, and Burkitt's like high grade B cell lymphoma; acute leukemias; acute lymphocytic leukemias; myeloblastic leukemias; acute myelocytic leukemias; promyelocytic leukemia; myelomonocytic leukemia; monocytic leukemia; erythroleukemia; granulocytic leukemia (chronic myelocytic leukemia); chronic lymphocytic leukemia; polycythemia vera; multiple myeloma; Waldenstrom's macroglobulinemia; heavy chain disease; and unclassifiable low-grade or high-grade B cell lymphomas.

It is recognized that the methods of the invention may be useful in preventing further tumor outgrowths arising during therapy. The methods of the invention are particularly useful in the treatment of subjects having low-grade B cell lymphomas, particularly those subjects having relapses following standard chemotherapy. Low-grade B cell lymphomas are more indolent than the intermediate- and high-grade B cell lymphomas and are characterized by a relapsing/remitting course. Thus, treatment of these lymphomas is improved using the methods of the invention, as relapse episodes are reduced in number and severity.

The antagonist anti-CD40 antibodies described herein may also find use in the treatment of inflammatory diseases and deficiencies or disorders of the immune system including, but not limited to, systemic lupus erythematosus, psoriasis, scleroderma, CREST syndrome, inflammatory myositis, Sjogren's syndrome, mixed connective tissue disease, rheumatoid arthritis, multiple sclerosis, inflammatory bowel disease, acute respiratory distress syndrome, pulmonary inflammation, idiopathic pulmonary fibrosis, osteoporosis, delayed type hypersensitivity, asthma, primary biliary cirrhosis, and idiopathic thrombocytopenic purpura.

In accordance with the methods of the present invention, at least one antagonist anti-CD40 antibody (or antigen-binding fragment thereof) as defined elsewhere herein is used to promote a positive therapeutic response with respect to a malignant human B cell. By "positive therapeutic response" with respect to cancer treatment is intended an improvement in the disease in association with the anti-tumor activity of these antibodies or fragments thereof, and/or an improvement in the symptoms associated with the disease. That is, an anti-proliferative effect, the prevention of further tumor outgrowths, a reduction in tumor size, a reduction in the number of cancer cells, and/or a decrease in one or more symptoms mediated by stimulation of CD40-expressing cells can be observed. Thus, for example, an improvement in the disease may be characterized as a complete response. By "complete response" is intended an absence of clinically detectable disease with normalization of any previously abnormal radiographic studies, bone marrow, and cerebrospinal fluid (CSF). Such a response must persist for at least one month following treatment according to the methods of the invention. Alternatively, an improvement in the disease may be categorized as being a partial response. By "partial response" is intended at least about a 50% decrease in all measurable tumor burden (i.e., the number of tumor cells present in the subject) in the absence of new lesions and persisting for at least one month. Such a response is applicable to measurable tumors only.

Tumor response can be assessed for changes in tumor morphology (i.e., overall tumor burden, tumor size, and the like) using screening techniques such as magnetic resonance imaging (MRI) scan, x-radiographic imaging, computed tomographic (CT) scan, bone scan imaging, and tumor biopsy sampling including bond marrow aspiration

(BMA). In addition to these positive therapeutic responses, the subject undergoing therapy with the antagonist anti-CD40 antibody or antigen-binding fragment thereof may experience the beneficial effect of an improvement in the symptoms associated with the disease. Thus for B cell tumors, the subject may experience a decrease in the so-called B symptoms, i.e., night sweats, fever, weight loss, and/or urticaria.

By "therapeutically effective dose or amount" is intended an amount of antagonist anti-CD40 antibody or antigen-binding fragment thereof that, when administered brings about a positive therapeutic response with respect to treatment of a patient with a disease comprising stimulation of CD40-expressing cells. In some embodiments of the invention, a therapeutically effective dose of the anti-CD40 antibody or fragment thereof is in the range from about 0.01 mg/kg to about 40 mg/kg, from about 0.01 mg/kg to about 30 mg/kg, from about 0.1 mg/kg to about 30 mg/kg, from about 1 mg/kg to about 30 mg/kg, from about 3 mg/kg to about 30 mg/kg, from about 3 mg/kg to about 25 mg/kg, from about 3 mg/kg to about 20 mg/kg, from about 5 mg/kg to about 15 mg/kg, or from about 7 mg/kg to about 12 mg/kg. It is recognized that the method of treatment may comprise a single administration of a therapeutically effective dose or multiple administrations of a therapeutically effective dose of the antagonist anti-CD40 antibody or antigen-binding fragment thereof.

A further embodiment of the invention is the use of antagonist anti-CD40 antibodies for diagnostic monitoring of protein levels in tissue as part of a clinical testing procedure, e.g., to determine the efficacy of a given treatment regimen. Detection can be facilitated by coupling the antibody to a detectable substance. Examples of detectable substances include various enzymes, prosthetic groups, fluorescent materials, luminescent materials, bioluminescent materials, and radioactive materials. Examples of suitable enzymes include horseradish peroxidase, alkaline phosphatase, β-galactosidase, or acetylcholinesterase; examples of suitable prosthetic group complexes include streptavidin/biotin and avidin/biotin; examples of suitable fluorescent materials include umbelliferone, fluorescein, fluorescein isothiocyanate, rhodamine, dichlorotriazinylamine fluorescein, dansyl chloride or phycoerythrin; an example of a luminescent material includes luminol; examples of bioluminescent materials include luciferase, luciferin, and aequorin; and examples of suitable radioactive material include ^{125}I, ^{131}I, ^{35}S, or ^{3}H.

The antagonist anti-CD40 antibodies can be used in combination with known chemotherapeutics and cytokines for the treatment of disease states comprising stimulated CD40-expressing cells. For example, the anti-CD40 antibodies of the invention can be used in combination with cytokines such as interleukin-2. In another embodiment, the anti-CD40 antibodies of the invention can be used in combination with rituximab (IDEC-C2B8; Rituxan®; IDEC Pharmaceuticals Corp., San Diego, California).

The anti-CD40 antibodies described herein can further be used to provide reagents, e.g., labeled antibodies that can be used, for example, to identify cells expressing CD40. This can be very useful in determining the cell type of an unknown sample. Panels of monoclonal antibodies can be used to identify tissue by species and/or by organ type. In a similar fashion, these anti-CD40 antibodies can be used to screen tissue culture cells for contamination (i.e., screen for the presence of a mixture of CD40-expressing and non-CD40 expressing cells in a culture).

Pharmaceutical Formulations and Modes of Administration

The antagonist anti-CD40 antibodies of this invention are administered at a concentration that is therapeutically effective to prevent or treat CD40-expressing cell-mediated diseases such as SLE, PBC, ITP, multiple sclerosis, psoriasis, Crohn's disease, graft rejection, and B-cell lymphoma. To accomplish this goal, the antibodies may be formulated using a variety of acceptable excipients known in the art. Typically, the antibodies are administered by injection, either intravenously or intraperitoneally. Methods to accomplish this administration are known to those of ordinary skill in the art. It may also be possible to obtain compositions which may be topically or orally administered, or which may be capable of transmission across mucous membranes.

Intravenous administration occurs preferably by infusion over a period of about 1 to about 10 hours, more preferably over about 1 to about 8 hours, even more preferably over about 2 to about 7 hours, still more preferably over about 4 to about 6 hours, depending upon the anti-CD40 antibody being administered. The initial infusion with the pharmaceutical composition may be given over a period of about 4 to about 6 hours with subsequent infusions delivered more quickly. Subsequent infusions may be administered over a period of about 1 to about 6 hours, preferably about 1 to about 4 hours, more

preferably about 1 to about 3 hours, yet more preferably about 1 to about 2 hours. The antibodies may be infused at a dose between 5 and 20 mg/kg/minute, more preferably between 7 and 15 mg/kg/minute. Suitable treatment regimens are disclosed in WO 00/27428 and WO 00/27433, which are incorporated herein by reference.

A pharmaceutical composition of the invention is formulated to be compatible with its intended route of administration. Examples of possible routes of administration include parenteral, (e.g., intravenous (IV), intramuscular (IM), intradermal, subcutaneous (SC), or infusion), oral and pulmonary (e.g., inhalation), nasal, transdermal (topical), transmucosal, and rectal administration. Solutions or suspensions used for parenteral, intradermal, or subcutaneous application can include the following components: a sterile diluent such as water for injection, saline solution, fixed oils, polyethylene glycols, glycerin, propylene glycol or other synthetic solvents; antibacterial agents such as benzyl alcohol or methyl parabens; antioxidants such as ascorbic acid or sodium bisulfite; chelating agents such as ethylenediaminetetraacetic acid; buffers such as acetates, citrates or phosphates and agents for the adjustment of tonicity such as sodium chloride or dextrose. pH can be adjusted with acids or bases, such as hydrochloric acid or sodium hydroxide. The parenteral preparation can be enclosed in ampoules, disposable syringes, or multiple dose vials made of glass or plastic.

The anti-CD40 antibodies are typically provided by standard technique within a pharmaceutically acceptable buffer, for example, sterile saline, sterile buffered water, propylene glycol, combinations of the foregoing, etc. Methods for preparing parenterally administrable agents are described in *Remington's Pharmaceutical Sciences* (18^{th} ed.; Mack Publishing Company, Eaton, Pennsylvania, 1990), herein incorporated by reference. See also, for example, WO 98/56418, which describes stabilized antibody pharmaceutical formulations suitable for use in the methods of the present invention.

The amount of at least one anti-CD40 antibody or fragment thereof to be administered is readily determined by one of ordinary skill in the art without undue experimentation. Factors influencing the mode of administration and the respective amount of at least one antagonist anti-CD40 antibody (or fragment thereof) include, but are not limited to, the particular disease undergoing therapy, the severity of the disease, the history of the disease, and the age, height, weight, health, and physical condition of

the individual undergoing therapy. Similarly, the amount of antagonist anti-CD40 antibody or fragment thereof to be administered will be dependent upon the mode of administration and whether the subject will undergo a single dose or multiple doses of this anti-tumor agent. Generally, a higher dosage of anti-CD40 antibody or fragment thereof is preferred with increasing weight of the patient undergoing therapy. The dose of anti-CD40 antibody or fragment thereof to be administered is in the range from about 0.003 mg/kg to about 50 mg/kg, preferably in the range of 0.01 mg/kg to about 40 mg/kg. Thus, for example, the dose can be 0.01 mg/kg, 0.03 mg/kg, 0.1 mg/kg, 0.3 mg/kg, 0.5 mg/kg, 1 mg/kg, 1.5 mg/kg, 2 mg/kg, 2.5 mg/kg, 3 mg/kg, 5 mg/kg, 7 mg/kg, 10 mg/kg, 15 mg/kg, 20 mg/kg, 25 mg/kg, 30 mg/kg, 35 mg/kg, 40 mg/kg, 45 mg/kg, or 50 mg/kg.

In another embodiment of the invention, the method comprises administration of multiple doses of antagonist anti-CD40 antibody or fragment thereof. The method may comprise administration of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40, or more therapeutically effective doses of a pharmaceutical composition comprising an antagonist anti-CD40 antibody or fragment thereof. The frequency and duration of administration of multiple doses of the pharmaceutical compositions comprising anti-CD40 antibody or fragment thereof can be readily determined by one of skill in the art without undue experimentation. Moreover, treatment of a subject with a therapeutically effective amount of an antibody can include a single treatment or, preferably, can include a series of treatments. In a preferred example, a subject is treated with antagonist anti-CD40 antibody or antigen-binding fragment thereof in the range of between about 0.1 to 20 mg/kg body weight, once per week for between about 1 to 10 weeks, preferably between about 2 to 8 weeks, more preferably between about 3 to 7 weeks, and even more preferably for about 4, 5, or 6 weeks. Treatment may occur annually to prevent relapse or upon indication of relapse. It will also be appreciated that the effective dosage of antibody or antigen-binding fragment thereof used for treatment may increase or decrease over the course of a particular treatment. Changes in dosage may result and become apparent from the results of diagnostic assays as described herein. Thus, in one embodiment, the dosing regimen includes a first administration of a therapeutically effective dose of at least one anti-CD40 antibody or fragment thereof on days 1, 7, 14, and 21 of a treatment period. In another embodiment, the dosing regimen includes a first

administration of a therapeutically effective dose of at least one anti-CD40 antibody or fragment thereof on days 1, 2, 3, 4, 5, 6, and 7 of a week in a treatment period. Further embodiments include a dosing regimen having a first administration of a therapeutically effective dose of at least one anti-CD40 antibody or fragment thereof on days 1, 3, 5, and 7 of a week in a treatment period; a dosing regimen including a first administration of a therapeutically effective dose of at least one anti-CD40 antibody or fragment thereof on days 1 and 3 of a week in a treatment period; and a preferred dosing regimen including a first administration of a therapeutically effective dose of at least one anti-CD40 antibody or fragment thereof on day 1 of a week in a treatment period. The treatment period may comprise 1 week, 2 weeks, 3 weeks, a month, 3 months, 6 months, or a year. Treatment periods may be subsequent or separated from each other by a day, a week, 2 weeks, a month, 3 months, 6 months, or a year.

The antagonist anti-CD40 antibodies present in the pharmaceutical compositions described herein for use in the methods of the invention may be native or obtained by recombinant techniques, and may be from any source, including mammalian sources such as, e.g., mouse, rat, rabbit, primate, pig, and human. Preferably such polypeptides are derived from a human source, and more preferably are recombinant, human proteins from hybridoma cell lines.

The pharmaceutical compositions useful in the methods of the invention may comprise biologically active variants of the antagonist anti-CD40 antibodies of the invention. Such variants should retain the desired biological activity of the native polypeptide such that the pharmaceutical composition comprising the variant polypeptide has the same therapeutic effect as the pharmaceutical composition comprising the native polypeptide when administered to a subject. That is, the variant anti-CD40 antibody will serve as a therapeutically active component in the pharmaceutical composition in a manner similar to that observed for the native antagonist antibody, for example 5.9 or 12.12 as expressed by the hybridoma cell line 5.9 or 12.12, respectively. Methods are available in the art for determining whether a variant anti-CD40 antibody retains the desired biological activity, and hence serves as a therapeutically active component in the pharmaceutical composition. Biological activity of antibody variants can be measured

using assays specifically designed for measuring activity of the native antagonist antibody, including assays described in the present invention.

Any pharmaceutical composition comprising an antagonist anti-CD40 antibody having the binding properties described herein as the therapeutically active component can be used in the methods of the invention. Thus liquid, lyophilized, or spray-dried compositions comprising one or more of the antagonist anti-CD40 antibodies of the invention may be prepared as an aqueous or nonaqueous solution or suspension for subsequent administration to a subject in accordance with the methods of the invention. Each of these compositions will comprise at least one of the antagonist anti-CD40 antibodies of the present invention as a therapeutically or prophylactically active component. By "therapeutically or prophylactically active component" is intended the anti-CD40 antibody is specifically incorporated into the composition to bring about a desired therapeutic or prophylactic response with regard to treatment, prevention, or diagnosis of a disease or condition within a subject when the pharmaceutical composition is administered to that subject. Preferably the pharmaceutical compositions comprise appropriate stabilizing agents, bulking agents, or both to minimize problems associated with loss of protein stability and biological activity during preparation and storage.

Formulants may be added to pharmaceutical compositions comprising an antagonist anti-CD40 antibody of the invention. These formulants may include, but are not limited to, oils, polymers, vitamins, carbohydrates, amine acids, salts, buffers, albumin, surfactants, or bulking agents. Preferably carbohydrates include sugar or sugar alcohols such as mono-, di-, or polysaccharides, or water soluble glucans. The saccharides or glucans can include fructose, glucose, mannose, sorbose, xylose, maltose, sucrose, dextran, pullulan, dextrin, α and β cyclodextrin, soluble starch, hydroxyethyl starch, and carboxymethylcellulose, or mixtures thereof. "Sugar alcohol" is defined as a C_4 to C_8 hydrocarbon having a hydroxyl group and includes galactitol, inositol, mannitol, xylitol, sorbitol, glycerol, and arabitol. These sugars or sugar alcohols may be used individually or in combination. The sugar or sugar alcohol concentration is between 1.0% and 7% w/v., more preferably between 2.0% and 6.0% w/v. Preferably amino acids include levorotary (L) forms of carnitine, arginine, and betaine; however, other amino acids may be added. Preferred polymers include polyvinylpyrrolidone (PVP) with an

average molecular weight between 2,000 and 3,000, or polyethylene glycol (PEG) with an average molecular weight between 3,000 and 5,000. Surfactants that can be added to the formulation are shown in EP Nos. 270,799 and 268,110.

Additionally, antibodies can be chemically modified by covalent conjugation to a polymer to increase their circulating half-life, for example. Preferred polymers, and methods to attach them to peptides, are shown in U.S. Patent Nos. 4,766,106; 4,179,337; 4,495,285; and 4,609,546; which are all hereby incorporated by reference in their entireties. Preferred polymers are polyoxyethylated polyols and polyethylene glycol (PEG). PEG is soluble in water at room temperature and has the general formula: R(O--CH_2 --CH_2)$_n$ O--R where R can be hydrogen, or a protective group such as an alkyl or alkanol group. Preferably, the protective group has between 1 and 8 carbons, more preferably it is methyl. The symbol n is a positive integer, preferably between 1 and 1,000, more preferably between 2 and 500. The PEG has a preferred average molecular weight between 1,000 and 40,000, more preferably between 2,000 and 20,000, most preferably between 3,000 and 12,000. Preferably, PEG has at least one hydroxy group, more preferably it is a terminal hydroxy group. It is this hydroxy group which is preferably activated to react with a free amino group on the inhibitor. However, it will be understood that the type and amount of the reactive groups may be varied to achieve a covalently conjugated PEG/antibody of the present invention.

Water-soluble polyoxyethylated polyols are also useful in the present invention. They include polyoxyethylated sorbitol, polyoxyethylated glucose, polyoxyethylated glycerol (POG), and the like. POG is preferred. One reason is because the glycerol backbone of polyoxyethylated glycerol is the same backbone occurring naturally in, for example, animals and humans in mono-, di-, triglycerides. Therefore, this branching would not necessarily be seen as a foreign agent in the body. The POG has a preferred molecular weight in the same range as PEG The structure for POG is shown in Knauf *et al.* (1988) *J. Bio. Chem.* 263:15064-15070, and a discussion of POG/IL-2 conjugates is found in U.S. Patent No. 4,766,106, both of which are hereby incorporated by reference in their entireties.

Another drug delivery system for increasing circulatory half-life is the liposome. Methods of preparing liposome delivery systems are discussed in Gabizon *et al.* (1982)

Cancer Research 42:4734; Cafiso (1981) *Biochem Biophys Acta* 649:129; and Szoka (1980) *Ann. Rev. Biophys. Eng.* 9:467. Other drug delivery systems are known in the art and are described in, *e.g.*, Poznansky *et al.* (1980) *Drug Delivery Systems* (R.L. Juliano, ed., Oxford, N.Y.) pp. 253-315; Poznansky (1984) *Pharm Revs* 36:277.

After the liquid pharmaceutical composition is prepared, it is preferably lyophilized to prevent degradation and to preserve sterility. Methods for lyophilizing liquid compositions are known to those of ordinary skill in the art. Just prior to use, the composition may be reconstituted with a sterile diluent (Ringer's solution, distilled water, or sterile saline, for example) that may include additional ingredients. Upon reconstitution, the composition is preferably administered to subjects using those methods that are known to those skilled in the art.

The following examples are offered by way of illustration and not by way of limitation.

EXPERIMENTAL

The antagonist anti-CD40 antibodies used in the examples below are 5.9 and 12.12. The 5.9 and 12.12 anti-CD40 antibodies are human IgG_1 subtype anti-human CD40 monoclonal antibodies (mAbs) generated by immunization of transgenic mice bearing the human IgG_1 heavy chain locus and the human K light chain locus (Xenomouse, Abgenix). As shown by FACS analysis, 5.9 and 12.12 bind specifically to human CD40 and can prevent CD40 ligand binding. Both mAbs can compete off CD40-ligand pre-bound to cell surface CD40. Both antibodies are strong antagonists and inhibit *in vitro* CD40 ligand-mediated proliferation of normal B cells, as well as cancer cells from NHL and CLL patients. *In vitro*, both antibodies kill cancer cell lines as well as primary cancer cells from NHL patients by ADCC. Dose-dependent anti-tumor activity was seen in a xenograft human lymphoma model. The binding affinity of 5.9 to human CD40 is 1.2×10^{-8} M and the binding affinity of 12.12 to human CD40 is 5×10^{-10} M.

Mouse hybridoma line 131.2F8.5.9 (CMCC#12047) and hybridoma line 153.8E2.D10.D6.12.12 (CMCC#12056) have been deposited with the American Type Culture Collection [ATCC; 10801 University Blvd., Manassas, Virginia 20110-2209 (USA)] under Patent Deposit Number PTA-5542 and PTA-5543, respectively.

The following protocols have been used in the examples described below.

ELISA Assay for Immunoglobulin Quantification

The concentrations of human IgM and IgG were estimated by ELISA. 96-well ELISA plates were coated with 2 μg/ml goat anti-human IgG MAb (The Jackson Laboratory, Bar Harbor, Maine) or with 2 μg/ml goat anti-human IgM MAb 4102 (Bio Source International, California) in 0.05 M carbonate buffer (pH 9.6), by incubation for 16 hours at 4°C. Plates were washed 3 times with PBS-0.05 % Tween-20 (PBS-Tween) and saturated with BSA for 1 hour. After 2 washes the plates were incubated for 2 hour at 37°C with different dilutions of the test samples. After 3 washes, bound Ig was detected by incubation for 2 hour at 37°C with 1 μg/ml peroxidase-labeled goat anti-human IgG MAb or goat anti-human IgM Mab. Plates were washed 4 times, and bound peroxidase activity was revealed by the addition of O-phenylenediamine as a substrate. Human IgG or IgM standards (Caltaq, Burlingame, California) was used to establish a standard curve for each assay.

Isolation of the Peripheral Blood Mononuclear Cells (PBMC) from Human Peripheral Blood

20 ml of Ficoll-Paque solution (low endotoxin; Pharmacia) was added per 50 ml polystyrene tube, in 3 tubes, 30 minutes before adding the blood. The Ficoll-Paque solution was warmed up to room temperature. 3 L of bleach in 1:10 dilution was prepared, and used to wash all the tubes and pipettes contacting the blood. The blood was layered on the top of the Ficoll-Paque solution without disturbing the Ficoll layer, at 1.5 ml blood/l ml of Ficoll-Paque. The tubes were centrifuged at 1700 rpm for 30 minutes at room temperature with the brake on the centrifuge turned off. As much of the top layer (plasma) as possible was removed, minimizing the vacuum in order to avoid removing the second layer of solution. The second layer, which contains the B and T lymphocytes, was collected using a sterile Pasteur pipette, and place in two 50-ml polystyrene tubes. The collection was diluted with 3 x the volume of cold RPMI with no additives, and the tubes were centrifuged at 1000 RPM for 10 minutes. The media was removed by aspiration, and the cells from both 50-ml tubes were resuspended in a total of

10 ml cold RPMI (with additives) and transferred to a 15-ml tube. The cells were counted using the hemacytometer, then centrifuged at 1000 RPM for 10 minutes. The media was removed and the cells resuspended in 4 ml RPMI. This fraction contained the PBMC.

Isolation of the B cells from PBMC

100 µl of Dynabeads (anti-h CD19) were placed in a 5-ml plastic tube. 3 ml of sterile PBS were added to the beads and mixed, and placed in the magnetic holder, then allowed to sit for 2 minutes. The solution was removed using a Pasteur pipette. 3 ml of sterile PBS were added, mixed, and placed in the magnetic holder, then allowed to sit for 2 minutes. This procedure with sterile PBS was repeated one more time for a total of 3 washes. The PBMC was added into the beads and incubated, while mixing, for 30 minutes at 40°C. The tube containing the PBMC and beads was placed into the magnetic holder for 2 minutes, then the solution was transferred to a new 5-ml tube in the magnetic holder. After 2 minutes, the solution was transferred to a new 15-ml tube. This step was repeated four more times, and the solutions of the first four times were collected in the 15-ml tube, then centrifuged at 1000 RPM for 5 minutes. This step produced the pellet for T-cell separation.

100 µl RPMI (with additives) was added to collect the beads, and the solution was transferred into a 0.7-ml tube. 10 µl of Dynal Detacha Beads were added into the suspension at room temperature, and it was allowed to rotate for 45 minutes. The suspension was transferred into a new 5-ml tube and 3-ml of RPMI (with additives) were added. The tube was placed in the magnetic holder for 2 minutes. The solution was transferred into a new 5-ml tube in the holder for 2 minutes, then to a 15-ml tube. The previous step was repeated three more times, collecting the solution in the 15-ml tube. The 15-ml tube was centrifuged at 1000 RPM for 10 minutes, and the cells resuspended in 10 ml RMPI. The washing step was repeated 2 more times for a total of 3 washes. The cells were counted before the last centrifugation. This step completed the B-cell purification. Cells were stored in 90% FCS and 10% DMSO and frozen at - 800°C.

Isolation of the T Cells

The human T cell Enrichment Column (R&D systems, anti-h CD 3 column kit) was prepared using 20 ml of 1 X column wash buffer by mixing 2 ml of l0 X column wash buffer and 18 ml of sterile distilled water. The column was cleaned with 70% ethanol and placed on top of a 15-ml tube. The top cap of the column was removed first to avoid drawing air into the bottom of the column. Next, the bottom cap was removed, and the tip was cleaned with 70% ethanol. The fluid within the column was allowed to drain into the 15-ml tube. A new sterile 15-ml tube was placed under the column after the column buffer had drained to the level of the white filter. The B-cell depleted PBMC fraction was suspended in 1 ml of buffer and added to the top of the column. The cells were allowed to incubate with the column at room temperature for 10 minutes. The T-cells were eluted from the column with 4 aliquots of 2 ml each of 1 X column wash buffer. The collected T-cells were centrifuged at 1000 RPM for 5 minutes. The supernatant was removed and the cells resuspended in 10 ml RPMI. Cells were counted and centrifuged one more time. The supernatant was removed, completing the T-cell purification. Cells were stored in 90% FCS and 10% DMSO and frozen at -80°C.

For the above procedures, the RPMI composition contained 10% FCS (inactivated at 56°C for 45 min), 1 % Pen/Strep (l00 u/ml Penicillin, 0.1 μg/ml Streptomycin), 1% Glutamate, 1% sodium puravate, 50 μM 2-ME.

Flow Cytofluorometric Assay

Ramos cells (106 cells/sample) were incubated in 100 μl primary antibody (10 μg/ml in PBS-BSA) for 20 min at 4°C. After 3 washes with PBS-BSA or HBSS- BSA, the cells were incubated in 100 μl FITC-labeled F(ab')2 fragments of goat anti-(human IgG) antibodies (Caltaq) for 20 min at 4°C. After 3 washes with PBS-BSA and 1 wash with PBS, the cells were resuspended in 0.5-ml PBS. Analyses were performed with a FACSCAN V (Becton Dickinson, San Jose, California).

Generation of Hybridoma Clones

Splenocytes from immunized mice were fused with SP 2/0 or P 3 x 63Ag8.653 murine myeloma cells at a ratio of 10:1 using 50% polyethylene glycol as previously described by de Boer *et al.* (1988) *J. Immunol. Meth.* 113:143. The fused cells were

resuspended in complete IMDM medium supplemented with hypoxanthine (0.1 mM), aminopterin (0.01 mM), thymidine (0.016 mM), and 0.5 ng/ml hIL-6 (Genzyme, Cambridge, Massachusetts). The fused cells were then distributed between the wells of 96-well tissue culture plates, so that each well contained 1 growing hybridoma on average.

After 10-14 days the supernatants of the hybridoma populations were screened for specific antibody production. For the screening of specific antibody production by the hybridoma clones, the supernatants from each well were pooled and tested for anti-CD 40 activity specificity by ELISA first. The positives were then used for fluorescent cell staining of EBV-transformed B cells as described for the FACS assay above. Positive hybridoma cells were cloned twice by limiting dilution in IMDM/FBS containing 0.5 ng/ml hIL-6.

Example 1: Production of Anti-CD40 Antibodies

Several fully human, antagonistic anti-CD40 monoclonal antibodies of IgG1 isotype were generated. Transgenic mice bearing the human IgG1 heavy chain locus and the human κ chain locus (Abgenix γ-1 xenomouse) were used to generate these antibodies. SF9 insect cells expressing CD40 extracellular domain were used as immunogen. A total of 31 mice spleens were fused with the mouse myeloma SP2/0 cells to generate 895 antibodies that recognize recombinant CD40 in ELISA (Tables 1A and 1B). On average approximately 10% of hybridomas produced in Abgenix xenomice may contain mouse lambda light chain instead of human kappa chain. The antibodies containing mouse light lambda chain were selected out. A subset of 260 antibodies that also showed binding to cell-surface CD40 were selected for further analysis. Stable hybridomas selected during a series of subcloning procedures were used for further characterization in binding and functional assays.

Table 1A. A Typical Fusion

	anti-CD40 titer				
Fusion #	(1:100K)	Fusi n Efficiency	# f wells scr ned	# f ELISA+	# ofcell surface+
153	3	100%	960	123	33
154	4.67	15%	140	0	0
155	6	~40%	960	3	3
156	3.17	~25%	220	1	0
157	4.67	90%	960	32	6
158	4.4	90%	960	23	8
159	1.17	100%	960	108	18
160	1.78	90%	960	30	5
Total			6120	320	73

Table 1B. Summary of Four Sets of Fusions

# of mice	ELISA-positive hybridomas	Cell surface positive Hybridomas
31	895	260

Table 2. Summary of initial set of data with anti-CD40 IgG1 antibodies

Mother Hybridoma	Hybridoma clones	cell surface binding	Antagonist	ADCC	CDC	CMCC#	V-region DNA sequence
	131.2F5.8.5.1	+++	++	ND	ND	ND	
131.2F5	131.2F5.8.5.9	+++	+++	++	-	12047	Yes
	131.2F5.8.5.11	+++	+++	++	-	12055	Yes
	153.3C5D8D7.8.4.7.1	++	ND	ND	ND	ND	
153.3C5	153.3C5D8D7.8.4.7.8	++	ND	ND	ND	ND	
	153.3C5D8D7.8.4.7.11	+++	+++	+	ND	ND	
	153.1D2.9.1	+++	ND	ND	ND	12067	
153.1D2	153.1D2.9.8	+++	+++	++	-	12057	
	153.1D2.9.12	+++	ND	ND	ND	12068	
	158.6F3.5.1	+++	+++	++	-	12054	Yes
158.6F3	158.6F3.5.7	+++	ND	ND	ND	12061	
	158.6F3.5.10	+++	ND	ND	ND	12062	
	153.8E2D10D6.12.7	+++	ND	ND	ND	12075	
153.8E2	153.8E2D10D6.12.9	+++	ND	ND	ND	12063	
	153.8E2D10D6.12.12	+++	+++	++++	-	12056	Yes
	155.2C2E9F12.2.10.4	+++	+/-	ND	ND	12064	
155.2C2	155.2C2E9F12.2.10.5	+++	ND	ND	ND	12065	
	155.2C2E9F12.2.10.6	+/-	ND	ND	ND	12066	
	166.5E6G12.1	+++	ND	ND	ND	12069	
166.5E6	166.5E6G12.3	+++	ND	ND	ND	12070	
	166.5E6G12.4	+++	+	ND	ND	12071	
177.8C10	177.8C10B3H9	+++	++	ND	ND	ND	
	183.4B3E11.6.1.5	++	ND	ND	ND	ND	
183.4B3	183.4B3E11.6.1.9	++	ND	ND	ND	ND	
	183.4B3E11.6.1.10	+++	++	ND	ND	ND	
	183.2G5D2.8.7	+++	+/-	ND	ND	ND	
183.2G5	183.2G5D2.8.8	+++	ND	ND	ND	ND	
	183.2G5D2.8.9	+++	ND	ND	ND	ND	
	184.6C11D3.2	++	ND	ND	ND	12078	
184.6C11	184.6C11D3.3	++	ND	ND	ND	12080	
	184.6C11D3.6	+/-	+/-	ND	ND	12079	
	185.3E4F12.5.6	+++	ND	ND	ND	12072	
185.3E4	185.3E4F12.5.11	+++	ND	ND	ND	12073	
	185.3E4F12.5.12	+++	+	ND	ND	12074	
	185.1A9E9.6.1	+	ND	ND	ND	ND	
185.1A9	185.1A9E9.6.6	+++	+++	+	ND	ND	
	185.9F11E10.3B5.1	+++	ND	ND	ND	ND	
185.9F11	185.9F11E10.3B5.8	+++	ND	ND	ND	ND	
	185.9F11E10.3B5.12	+++	+++	ND	ND	ND	

Clones from 7 mother hybridomas were identified to have antagonistic activity. Based on their relative antagonistic potency and ADCC activities, two hybridoma clones were selected. Their names are: 131.2F8.5.9 (5.9) and 153.8E2.D10.D6.12.12 (12.12).

Clones from 7 other hybridomas were identified as having antagonistic activity (Table 2 above). Based on their relative antagonistic potency and ADCC activities, two hybridoma clones were selected for further evaluation. They are named 131.2F8.5.9 (5.9) and 153.8E2.D10.D6.12.12 (12.12). The binding profile of these two antibodies to CD40+ lymphoma cell line is shown as a flow cytometric histogram in Figure 1.

Example 2: Polynucleotide and Amino Acid Sequences of Human Anti-CD40 Antibodies

The cDNAs encoding the variable regions of the candidate antibodies were amplified by PCR, cloned, and sequenced. The amino acid sequences for the light chain and heavy chain of the 5.9 antibody are set forth in Figs. 11A and 11B, respectively. The amino acid sequences for the light chain and heavy chain of the 12.12 antibody are set forth in Figs. 10A and 10B, respectively. The nucleotide sequences encoding the light chain and heavy chain of the 12.12 antibody are set forth in Figs. 12A and 12B, respectively.

As expected for antibodies derived from independent hybridomas, there is substantial variation in the nucleotide sequences in the complementarity determining regions (CDRs) Figure 2. The diversity in the CDR3 region of V_H is believed to most significantly determine antibody specificity.

Example 3: Effect of 5.9 and 12.12 on the CD40/CD40L Interaction *In vitro*

The candidate antibodies 5.9 and 12.12 prevent the binding of CD40 ligand to cell surface CD40 and displace the pre-bound CD40 ligand. Antibodies 5.9 and 12.12 were tested for their ability to prevent CD40-ligand binding to CD40 on the surface of a lymphoma cell line (Ramos). Binding of both antibodies (unlabeled) prevented the subsequent binding of PE-CD40 ligand as measured by flow cytometric assays (Figure 3A). In a second set of assays the two antibodies were tested for their ability to replace CD40 ligand pre-bound to cell surface CD40. Both antibodies were effective for competing out pre-bound CD40 ligand, with 5.9 being slightly more effective than 12.12 (Figure 3B).

Example 4: 5.9 and 12.12 Bind to a Different Epitope on CD40 Than 15B8

The candidate monoclonal antibodies 5.9 and 12.12 compete with each other for binding to CD40 but not with 15B8, an IgG_2 anti-CD40 mAb (see International Publication No. WO 02/28904). Antibody competition binding studies using Biacore were designed using CM5 biosensor chips with protein A immobilized via amine coupling, which was used to capture either anti-CD40, 12.12, or 15B8. Normal association/dissociation binding curves are observed with varying concentrations of CD40-his (data not shown). For competition studies, either 12.12 or 15B8 were captured onto the protein A surface. Subsequently a CD40-his / 5.9 Fab complex (100 nM CD40:1 µM 5.9 Fab), at varying concentrations, was flowed across the modified surface. In the case of 12.12, there was no association of the complex observed, indicating 5.9 blocks binding of 12.12 to CD40-his. For 15B8, association of the Fab 5.9 complex was observed indicating 5.9 does not block binding of 15B8 to CD40 binding site. However, the off rate of the complex dramatically increased (data not shown).

It has also been determined that 15B8 and 12.12 do not compete for CD40-his binding. This experiment was set up by capturing 12.12 on the protein A biosensor chip, blocking residual protein A sites with control $hIgG_1$, binding CD40-his and then flowing 15B8 over the modified surface. 15B8 did bind under these conditions indicating 12.12 does not block 15B8 from binding to CD40.

Example 5: Binding Properties of Selected Hybridomas

Protein A was immobilized onto CM5 biosensor chips via amine coupling. Human anti-CD40 monoclonal antibodies, at 1.5 µg/ml, were captured onto the modified biosensor surface for 1.5 minutes at 10 µl/min. Recombinant soluble CD40-his was flowed over the biosensor surface at varying concentrations. Antibody and antigen were diluted in 0.01 M HEPES pH 7.4, 0.15 M NaCl, 3 mM EDTA, 0.005% Surfactant P20 (HBS-EP). Kinetic and affinity constants were determined using the Biaevaluation software with a 1:1 interaction model/global fit.

As shown in Table 3 below, there is 121-fold difference in the off rate of 5.9 and 12.12 resulting in 24-fold higher affinity for 12.12.

Antibody	ka (M-1 sec-1))	kd (sec-1)	KD (nM)
Anti-CD40, 5.9	$(12.35 \pm 0.64) \times 10^5$	$(15.0 \pm 1.3) \times 10^{-3}$	12.15 ± 0.35
Anti-CD40, 12.12	$(2.41 \pm 0.13) \times 10^5$	$(1.24 \pm 0.06) \times 10^{-4}$	0.51 ± 0.02

Example 6: 5.9 and 12.12 are Potent Antagonists for CD40-Mediated Proliferation of Human Lymphocytes from Normal Subjects

Engagement of CD40 by CD40 ligand induces proliferation of human B cells. An antagonistic anti-CD40 antibody is expected to inhibit this proliferation. Two candidate antibodies (5.9 and 12.12) were tested for their ability to inhibit CD40 ligand-induced proliferation of PBMC from normal human subjects. Formaldehyde-fixed CHO cells transfectant-expressing CD40 ligand (CD40L) were used as a source of CD40 ligand. The proliferation was measured by tritiated-thymidine incorporation. Both antibodies were found to be very effective for inhibiting CD40 ligand-induced proliferation of human PBMC (Table 4A, mAb 5.9, Table 4B, mAb 12.12). The experiment was performed with multiple donors of PBMC (n=12 for 5.9 and n=2 for 12.12) to ensure that the observed inhibition was not a peculiarity of cells from a single donor. A wide range of antibody concentrations (0.01 μg/ml to 100 μg/ml) was used in these assays. Nearly complete inhibition of CD40 ligand-induced proliferation could be achieved at 0.1 μg/ml concentration of antibodies in most cases. Based on the current data set, both candidate antibodies seem similar in their potency for inhibition of CD40 ligand-induced proliferation of normal PBMC.

Table 4A. Effect of mAb 5.9 on CD40L-induced PBMC proliferation.

Exp#	PBMC alone	CHO-CD40L alone	PBMC+ CHO-CD40L	Abs Conc (µg/ml)	huIgG1 CPM	huIgG1 % of inhibition	5.9 CPM	5.9 % f inhibition
PBMC-010	1851	121	4436	1	5080	-26	2622	74
	1851	121	4436	0.25	5498	-43	2907	62
	1851	121	4436	0.0625	6029	-65	2619	74
	1851	121	4436	0.0156	5814	-56	1199	131
PBMC-011 Donor#1	2162	178	8222	10	13137	-84	2252	101
	2162	178	8222	1	11785	-61	1438	115
	2162	178	8222	0.1	10758	-43	1249	119
	2162	178	8222	0.01	11322	-53	4705	60
Donor#2	2216	294	7873	10	16679	-164	2362	103
	2216	294	7873	1	14148	-117	1202	124
	2216	294	7873	0.1	12422	-85	756	133
	2216	294	7873	0.01	13870	-112	6606	24
Donor#3	2396	241	11021	10	11641	-7	2631	100
	2396	241	11021	1	13528	-30	1450	114
	2396	241	11021	0.1	12176	-14	990	120
	2396	241	11021	0.01	11895	-10	5357	68
Donor#4	4552	133	15301	10	22098	-64	3768	109
	4552	133	15301	1	19448	-39	2040	125
	4552	133	15301	0.1	18398	-29	1728	128
	4552	133	15301	0.01	22767	-70	9481	55
PBMC-012	777	117	6041	10	7327	-25	2150	76
	777	117	6041	1	6212	-3	1550	87
	777	117	6041	0.1	7006	-19	828	101
	777	117	6041	0.01	7524	-29	1213	94
PBMC-014	1857	73	7889	100	9399	-25	3379	76
	1857	73	7889	20	8120	-4	3870	67
	1857	73	7889	4	8368	-8	2552	90
	1857	73	7889	0.8	9564	-28	1725	103
PBMC-015 Donor#1	3203	127	10485	100	15425	-69	1497	126
	3203	127	10485	20	11497	-14	1611	124
	3203	127	10485	4	11641	-16	1359	128
	3203	127	10485	0.8	12807	-32	1490	126
Donor#2	3680	175	15145	100	21432	-56	1792	118
	3680	175	15145	20	16998	-16	1779	118
	3680	175	15145	4	17729	-23	1965	117
	3680	175	15145	0.8	17245	-19	2217	115
Donor#3	2734	152	19775	100	22967	-19	1664	107
	2734	152	19775	20	21224	-9	1848	106
	2734	152	19775	4	20658	-5	1534	108
	2734	152	19775	0.8	18923	5	1262	110
PBMC-016	1118	36	13531	0.1	10928	21	745	103
	1118	36	13531	0.05	11467	17	962	102
	1118	36	13531	0.01	11942	13	3013	85
PBMC-017	962	75	12510	1	13597	-9	258	107

Table 4A. Effect of mAb 5.9 on CD40L-induced PBMC proliferation (cont.).

Average % inhibition f human PBMC at 100 μg/ml	-42	107
Average % inhibition f human PBMC at 10 μg/ml	-69	98
Average % inhibition of human PBMC at 1 μg/ml	-41	107
Average % inhibition of human PBMC at 0.1 μg/ml	-28	117
Average % inhibition of human PBMC at 0.01 μg/ml	-44	64
Average % inhibition of human PBMC	-35	101

% of inhibition:

100-(CPM with Abs-PBMC alone-CHO-CD40L alone)/(CPM of PBMC+CHO-CD40L-PBMC alone-CHO-CD40L alone)*100%

Table 4B. Effect of mAb 12.12 on CD40L-induced PBMC proliferation.

Exp#		PBMC alone	CHO-CD40L alone	PBMC+ CHO-CD40L	Abs Conc (μg/ml)	huIgG1 CPM	huIgG1 % of Inhibition	12.12 CPM	12.12 % of Inhibition	IC50(nM)
PBMC-025	Donor#1	4051	32	42292	0.1	33354	23	440	110	
		4051	32	42292	0.01	37129	14	8696	88	
		4051	32	42292	0.001	40271	5	32875	25	
		4051	32	42292	0.0001	40034	6	37261	13	24.22
	Donor#2	2260	31	14987	0.1	15767	-6	365	115	
		2260	31	14987	0.01	17134	-17	6734	65	
		2260	31	14987	0.001	20142	-41	16183	-9	
		2260	31	14987	0.0001	17847	-23	16187	-9	65.96
PBMC-026	Donor#1	2039	35	19071	0.1	17136	11	624	109	
		2039	35	19071	0.01	16445	15	6455	74	
		2039	35	19071	0.001	16195	17	17833	7	
		2039	35	19071	0.0001	18192	5	17924	7	45
	Donor#2	2016	64	17834	0.1	17181	4	2078	100	
		2016	64	17834	0.01	16757	7	10946	44	
		2016	64	17834	0.001	18613	-5	17924	-1	
		2016	64	17834	0.0001	17169	4	18569	-5	84
PBMC-028	Donor#1	4288	45	22547	1	18204	24	2098	112	
		4288	45	22547	0.1	20679	10	1827	114	
		4288	45	22547	0.01	22799	-1	6520	88	
		4288	45	22547	0.001	23547	-5	22327	1	
		4288	45	22547	0.0001	24778	-12	24124	-9	30.07
	Donor#2	2148	58	54894	1	48545	12	5199	94	
		2148	58	54894	0.1	45708	17	5091	95	
		2148	58	54894	0.01	51741	6	18890	68	
		2148	58	54894	0.001	52421	5	50978	7	
		2148	58	54894	0.0001	54778	0	52581	4	34.68
PBMC-029	Donor#1	609	69	10054	0.1	11027	-10	2098	85	
		609	69	10054	0.01	10037	0	1827	88	
		609	69	10054	0.001	10222	-2	6520	38	
		609	69	10054	0.0001	11267	-13	22327	-131	28.06
	Donor#2	7737	57	23132	0.1	21254	12	2536	134	
		7737	57	23132	0.01	21726	9	10249	84	
		7737	57	23132	0.001	22579	4	23380	-2	
		7737	57	23132	0.0001	22491	4	23183	0	55.35
PBMC-030	Donor#1	2739	47	53426	0.1	60116	-13	2132	101	
		2739	47	53426	0.01	56411	-6	14297	77	
		2739	47	53426	0.001	59167	-11	55868	-5	
		2739	47	53426	0.0001	59290	-12	60865	-15	35.52
	Donor#2	4310	50	53781	0.1	52881	2	3208	102	
		4310	50	53781	0.01	51741	4	30716	47	
		4310	50	53781	0.001	53072	1	53628	0	
		4310	50	53781	0.0001	58045	-9	54343	-1	102.88
PBMC-032	Donor#1	2458	42	14058	0.1	16579	-22	636	116	40.36
		2458	42	14058	0.01	19250	-45	3358	93	

	2458	42	14058	0.001	19852	-50	20639	-57	
	2458	42	14058	0.0001	19161	-44	18907	-42	
Average % inhibiti n of human PBMC at 0.1 μg/ml						**3**		**107**	
Average % inhibition of human PBMC at 0.01 μg/ml						**-1**		**74**	
Average % inhibition of human PBMC at 0.001 μg/ml						**-7**		**0**	
Average % inhibition of human PBMC at 0.0001μg/ml						**-8**		**-17**	49.65
% of inhibition: 100-(CPM with Abs-PBMC alone-CHO-CD40L alone)/(CPM of PBMC+CHO-CD40L-PBMC alone-CHO-CD40L alone)*100%									

In addition to B cells, human PBMC also contain natural killer cells that can mediate antibody dependent cytotoxicity (ADCC). To clarify the mechanism of antibody-mediated inhibition of proliferation, assays were performed with B cells purified from human PBMC. Similar to results obtained with PBMC, both antibodies potently inhibited the CD40 ligand-induced proliferation of purified B cells (Table 5, n=3). These data demonstrate that the antagonistic activity of the candidate antibodies, and not the mechanism of ADCC, is the cause of proliferation inhibition in these assays.

Table 5. Effect of anti-CD40 antibodies on CD40 ligand-induced proliferation of purified human B cells

		CPM				HuIgG1		5.9		12.12	
Exp#	**Donor #**	**B cells**	**CHO-CD40L**	**B cells + CHO-CD40L**	**Abs Conc(μg/ml)**	**CPM**	**% inhibition**	**CPM**	**% inhibition**	**CPM**	**% inhibition**
B cell-004	1	418	89	3132	100	429	**103**	271	**109**	152	**114**
		418	89	3132	20	3193	**-2**	316	**107**	222	**111**
		418	89	3132	4	3175	**-2**	144	**114**	235	**110**
		418	89	3132	0.8	6334	**-122**	245	**110**	63	**117**
	2	81	73	27240	100	28311	**-4**	85	**100**	77	**100**
		81	73	27240	20	24707	**9**	65	**100**	94	**100**
		81	73	27240	4	23081	**15**	108	**100**	68	**100**
		81	73	27240	0.8	26252	**4**	87	**100**	77	**100**
B cell-005	3	267	75	24552	1	25910	**-6**	291	**100**	102	**101**
		267	75	24552	0.1	28447	**-16**	259	**100**	108	**101**
		267	75	24552	0.01	26706	**-9**	2957	**89**	4922	**81**
Average % inhibition							**-3**		**103**		**103**

% of inhibition: 100-(CPM with Abs-B cells alone-CHO-CD40L alone)/(CPM of B cell with CHO-CD40L-B cells alone-CHO-CD40L alone)*100%

Example 7: 5.9 and 12.12 Do Not Induce Strong Proliferation of Human B Cells from Normal Subjects

CD40 ligand activates normal B cells and B-cell lymphoma cells to proliferate. Binding of some anti-CD40 antibodies (agonist) can provide a similar stimulatory signal for the proliferation of normal and cancer B cells. Antibodies with strong B cell

stimulatory activity are not suitable candidates for therapeutic treatment of B cell lymphomas. The two candidate antibodies were tested for their ability to induce proliferation of B cells from normal volunteer donors. The B cells purified from normal donor PBMC were cultured with varying concentrations of candidate antibodies (range of 0.001 to 100 μg/ml) for a total of 4 days. The B cell proliferation was measured by incorporation of tritiated thymidine. While the CD40 ligand presented on CHO cells induced vigorous proliferation of B cells resulting in an average stimulation index (SI) of 145, the candidate antibodies induced only a weak proliferation with a stimulation index of 2.89 and 5.08 for 12.12 and 5.9, respectively (n=3) (Table 6).

Table 6. Proliferation of B cells purified from normal human subjects in response to candidate anti-CD40 mAbs

		B cells	Bcells+CHO-CD40L			B cells+huIgG1		B cells+5.9		B cells+12.12	
Exp#	Donor#	CPM	CPM	S. index(1)	Abs conc (ug/ml)	CPM	S. index(2)	CPM	S. index (2)	CPM	S. index(2)
B cell-004	1	418	3132	7.49	100	498	1.19	401	0.96	458	1.10
Frozen		418	3132		20	245	0.59	232	0.56	370	0.89
		418	3132		4	241	0.58	232	0.56	211	0.50
		418	3132		0.8	376	0.90	298	0.71	230	0.55
Frozen	2	81	27240	336.30	100	34	0.42	454	5.60	122	1.51
		81	27240		20	48	0.59	706	8.72	255	3.15
		81	27240		4	41	0.51	567	7.00	367	4.53
		81	27240		0.8	34	0.42	736	9.09	408	5.04
B cell-005	3	267	24552	91.96	1	691	2.59	2101	7.87	1223	4.58
		267	24552		0.1	686	2.57	2267	8.49	1557	5.83
		267	24552		0.01	808	3.03	2203	8.25	1027	3.85
		267	24552		0.001	567	2.12	846	3.17	826	3.09
Average Stimulation Index (SI)				**145.25**			**1.29**		**5.08**		**2.88**

S. index(1): = CPM (B cells+CHO-CD40L)/CPM (B cells alone)
S. index(2): = CPM (B cells+Abs)/CPM (PBMC alone)

In addition to B cells, human PBMC contain cell types that bear Fc receptors (FcR) for IgG1 molecules that can provide cross linking of anti-CD40 antibodies bound to CD40 on B cells. This cross-linking could potentially enhance stimulatory activity of anti-CD40 antibodies. To confirm the lack of B cell stimulatory activity of 5.9 and 12.12 antibodies in the presence of cross-linking cells, proliferation experiments were performed with total PBMC containing B cells as well as FcR+ cells. Data from these experiments (Table 7A, mAb 5.9; Table 7B, mAb 12.12) confirm that these candidate antibodies even in the presence of FcR-bearing cells in general do not stimulate B cells to

proliferate over background proliferation induced by control human IgG1 (n=10). The CD40 ligand induced an average stimulation index (SI) SI of 7.41. The average SI with candidate antibodies were 0.55 and 1.05 for 12.12 and 5.9, respectively. Only one of the 10 donor PBMC tested showed some stimulatory response to 5.9 antibody (donor #2 in Table 7). The lack of stimulatory activity by candidate mAbs was further confirmed by measuring the PBMC proliferation in response to candidate anti-CD40 antibodies immobilized on the plastic

Table 7A. Proliferation of PBMC from normal human subjects in response to mAb 5.9.

Exp#		PBMC	PBMC+CHO-CD40L CPM	index(1)	Abs conc (μg/ml)	PBMC+hulgG1 CPM	index(2)	PBMC+5.9 CPM	index(2)
PBMC-010		1417	5279	3.73	1	1218	0.86	5973	4.22
		1417	5279		0.25	1712	1.21	4815	3.40
		1417	5279		0.0625	1449	1.02	3642	2.57
		1417	5279		0.0156	1194	0.84	3242	2.29
PBMC-011	Donor#1	2138	8247	3.86	10	3047	1.43	3177	1.49
		2138	8247		1	2726	1.28	3617	1.69
		2138	8247		0.1	2026	0.95	2011	0.94
		2138	8247		0.01	2424	1.13	1860	0.87
	Donor#2	2374	11561	4.87	10	4966	2.09	4523	1.91
		2374	11561		1	2544	1.07	2445	1.03
		2374	11561		0.1	2177	0.92	1462	0.62
		2374	11561		0.01	4672	1.97	1896	0.80
	Donor#3	3229	7956	2.46	10	5035	1.56	2119	0.66
		3229	7956		1	2826	0.88	1099	0.34
		3229	7956		0.1	2277	0.71	1052	0.33
		3229	7956		0.01	3078	0.95	1899	0.59
	Donor#4	4198	14314	3.41	10	5012	1.19	5176	1.23
		4198	14314		1	3592	0.86	4702	1.12
		4198	14314		0.1	5298	1.26	4319	1.03
		4198	14314		0.01	5758	1.37	5400	1.29
PBMC-014		2350	8787	3.74	100	2722	1.16	2471	1.05
		2350	8787		20	2315	0.99	2447	1.04
		2350	8787		4	2160	0.92	1659	0.71
		2350	8787		0.8	2328	0.99	1671	0.71
PBMC-015	Donor#1	3284	12936	3.94	100	3598	1.10	1682	0.51
		3284	12936		20	2751	0.84	1562	0.48
		3284	12936		4	3135	0.95	1105	0.34
		3284	12936		0.8	4027	1.23	1419	0.43
	Donor#2	6099	19121	3.14	100	2999	0.49	5104	0.84
		6099	19121		20	4025	0.66	3917	0.64
		6099	19121		4	4496	0.74	3341	0.55
		6099	19121		0.8	3834	0.63	4139	0.68
	Donor#3	2479	19826	8.00	100	3564	1.44	1204	0.49
		2479	19826		20	1874	0.76	782	0.32
		2479	19826		4	1779	0.72	634	0.26
		2479	19826		0.8	2274	0.92	937	0.38
PBMC-016		1148	15789	13.75	0.1	1255	1.09	1036	0.90
		1148	15789		0.05	1284	1.12	871	0.76
		1148	15789		0.01	1446	1.26	952	0.83
Average SI of PBMC				5.09			1.06		1.03

index(1): =(PBMC+CHO-CD40L)/PBMC

index(2): =(PBMC+Abs)/PBMC

Table 7B. Proliferation of PBMC from normal human subjects in response to mAb 12.12.

Exp#		PBMC	PBMC+CHO-CD40L CPM	PBMC+CHO-CD40L ind x(1)	Abs conc (µg/ml)	PBMC+hulgG1 CPM	PBMC+hulgG1 index(2)	PBMC+12.12 CPM	PBMC+12.12 index(2)
PBMC-025	Donor#1	4051	42292	10.44	0.1	2909	0.72	2451	0.61
		4051	42292		0.01	4725	1.17	8924	2.20
		4051	42292		0.001	8080	1.99	8782	2.17
		4051	42292		0.0001	4351	1.07	4342	1.07
	Donor#2	2260	14987	6.63	0.1	2538	1.12	6741	2.98
		2260	14987		0.01	3524	1.56	8921	3.95
		2260	14987		0.001	3159	1.40	4484	1.98
		2260	14987		0.0001	2801	1.24	2533	1.12
PBMC-026	Donor#1	2085	18313	8.78	0.1	1386	0.66	2761	1.32
		2085	18313		0.01	2871	1.38	3162	1.52
		2085	18313		0.001	2602	1.25	3233	1.55
		2085	18313		0.0001	1709	0.82	1766	0.85
	Donor#2	676	18054	26.71	0.1	660	0.98	2229	3.30
		676	18054		0.01	2864	4.24	1238	1.83
		676	18054		0.001	693	1.03	1507	2.23
		676	18054		0.0001	984	1.46	811	1.20
PBMC-027	Donor#1	2742	13028	4.75	0.1	4725	1.72	2795	1.02
		2742	13028		0.01	4575	1.67	5353	1.95
		2742	13028		0.001	3218	1.17	3501	1.28
		2742	13028		0.0001	5107	1.86	4272	1.56
	Donor#2	1338	11901	8.89	0.1	1633	1.22	1943	1.45
		1338	11901		0.01	1520	1.14	5132	3.84
		1338	11901		0.001	1517	1.13	2067	1.54
		1338	11901		0.0001	1047	0.78	2076	1.55
PBMC-028	Donor#1	4288	22547	5.26	0.1	3686	0.86	2525	0.59
		4288	22547		0.01	3113	0.73	2047	0.48
		4288	22547		0.001	4414	1.03	3515	0.82
		4288	22547		0.0001	2452	0.57	4189	0.98
	Donor#2	2148	54894	25.56	0.1	9127	4.25	5574	2.59
		2148	54894		0.01	4566	2.13	6515	3.03
		2148	54894		0.001	5285	2.46	5919	2.76
		2148	54894		0.0001	4667	2.17	4298	2.00
PBMC-029	Donor#1	609	10054	16.51	0.1	359	0.59	363	0.60
		609	10054		0.01	473	0.78	956	1.57
		609	10054		0.001	461	0.76	1159	1.90
		609	10054		0.0001	625	1.03	558	0.92
	Donor#2	7737	23132	2.99	0.1	4940	0.64	3493	0.45
		7737	23132		0.01	6041	0.78	3644	0.47
		7737	23132		0.001	5098	0.66	5232	0.68
		7737	23132		0.0001	5135	0.66	5241	0.68
PBMC-030	Donor#1	4164	57205	13.74	10	2713	0.65	1046	0.25
		4164	57205		1	3627	0.87	1576	0.38
		4164	57205		0.1	4590	1.10	1512	0.36
		4164	57205		0.01	4384	1.05	2711	0.65
	Donor#2	3324	53865	16.20	10	6376	1.92	4731	1.42
		3324	53865		1	4720	1.42	5219	1.57
		3324	53865		0.1	3880	1.17	5869	1.77
		3324	53865		0.01	3863	1.16	5657	1.70

PBMC-032	Donor#1	1808	15271	8.45	10	2349	1.30	4790	2.65
		1808	15271		1	3820	2.11	5203	2.88
		1808	15271		0.1	2098	1.16	6332	3.50
		1808	15271		0.01	1789	0.99	5005	2.77
Average SI f PBMC				11.92			1.30		1.62

index(1): =CPM of (PBMC+CHO-CD40L)/CPM of PBMC
index(2): =CPM of (PBMC+Abs)/CPM of PBMC

surface of the culture wells (n=2). The average SI with CD40 ligand, 12.12, and 5.9 stimulation were 22, 0.67, and 1.2, respectively (Table 8). Taken together these data show that the candidate antiCD40 antibodies do not possess strong B cell stimulatory properties.

Table 8. Proliferation of PBMC from normal human subjects in response to immobilized anti-CD40 antibodies

	PBMC	PBMC+CHO-CD40L			PBMC+huIgG1		PBMC+5.9		PBMC+12.12	
Exp#	CPM	CPM	S.Index (1)	Abs conc (ug/ml)	CPM	S. index(2)	CPM	S.index (2)	CPM	S.index (2)
PBMC-012	225	6808	30.26	10	279	1.24	734	3.26	200	0.89
	225	6808		1	175	0.78	178	0.79	161	0.72
	225	6808		0.1	156	0.69	226	1.00	249	1.11
	225	6808		0.01	293	1.30	232	1.03	254	1.13
Immoblize-004	857	11701	13.65	1000	479	0.56	1428	1.67	384	0.45
	857	11701		100	543	0.63	839	0.98	265	0.31
	857	11701		10	487	0.57	411	0.48	262	0.31
	857	11701		1	632	0.74	372	0.43	376	0.44
Average Stimulation index			**21.96**			**0.81**		**1.21**		**0.67**

S. index (1): = CPM (PBMC+CHO-CD40L)/CPM (PBMC)
S. index (2): = CPM (PBMC+mAbs)/CPM (PBMC)

Example 8: 5.9 and 12.12 Are Able to Kill CD40-Bearing Target Cells by ADCC

The candidate antibodies can kill CD40-bearing target cells (lymphoma lines) by the mechanism of ADCC. Both 5.9 and 12.12 are fully human antibodies of IgG1 isotype and are expected to have the ability to induce the killing of target cells by the mechanism of ADCC. They were tested for their ability to kill cancer cell lines in *in vitro* assays. Two human lymphoma cell lines (Ramos and Daudi) were selected as target cells for these assays. PBMC or enriched NK cells from 8 normal volunteer donors were used as effector cells in these assays. A more potent ADCC response was observed with 12.12 compared with 5.9 against both the lymphoma cancer cell line target cells. Lymphoma cell lines also express CD20, the target antigen for rituximab (Rituxan®), which allowed

for comparison of the ADCC activity of these two candidate mAbs with rituximab ADCC activity. For lymphoma cell line target, an average specific lysis of 35%, 59%, and 47% was observed for 5.9, 12.12, and rituximab respectively when used at 1 μg/ml concentration (Table 9). The two antibodies did not show much activity in complement dependent cytotoxicity (CDC) assays.

Table 9. Anti-CD40 mAB dependent killing of lymphoma cell lines by ADCC.

Anti-CD40 mAb dependent killing of lymphoma cell lines by ADCC										
			Target cells : Human lymphoma cell line (Ramos or Daudi)							
					5.9		12.12		Rituxan	
Exp#	Effector cell	ET ratio	%lysis IgG1	Abs conc(ug/ml)	%lysis	%lysis - % lysis IgG1	%lysis	%lysis-% lysis IgG1	%lysis	%lysis-% lysis IgG1
ADCC-005	huNK	3	17.05	5	30.75	13.70	66.22	48.17	ND	ND
Alamar Blue	huNK	3	40.81	5	58.62	17.81	87.87	47.06	ND	ND
ADCC-006	huNK	2	-3.09	10	3.50	6.59	43.71	46.8	34.82	37.91
Alamar Blue			-8.62	1	-10.10	-1.48	45.13	53.75	37.07	45.69
			-11	0.1	-14.80	-3.80	39.82	50.82	33.61	44.61
			-4.54	0.01	2.53	7.07	50.07	54.61	28.49	33.03
51Cr	huNK	5	1.5	10	32.09	30.59	47.24	45.742	ND	ND
			2.4	1	18.01	15.61	37.42	35.022	ND	ND
			2.5	0.1	14.67	12.17	37.63	35.131	ND	ND
ADCC-009	huNK	10	2.32	5	66.20	63.88	97.70	95.38	86.2	83.88
Calcien AM			0.48	1	67.20	66.72	123.00	122.52	88.2	87.72
			-1.43	0.2	78.40	79.83	118.00	119.43	88.8	90.23
			3.39	0.04	69.10	65.71	109.00	105.61	84.9	81.51
ADCC-011	huNK	8	3.18	1	15.36	12.19	51.59	48.42	22.44	19.27
Calcien AM			4.58	0.01	7.39	2.81	46.80	42.22	14.68	10.10
			5.41	0.002	6.35	0.94	5.10	-0.31	9.58	4.16
			7.03	0.0004	7.76	0.73	5.99	-1.04	5.99	-1.04
ADCC-012	huNK	10	13.34	10	73.31	59.97	117.80	104.46	50.75	37.41
Calcien AM			13.50	1	74.76	61.26	88.64	75.14	65.97	52.47
			12.27	0.01	58.52	46.25	72.88	60.61	50.16	37.89
			13.61	0.005	57.50	43.89	69.45	55.84	39.28	25.67
			11.95	0.001	56.81	44.86	66.17	53.22	33.07	21.12
ADCC-013	PBMC	100	2.54	1	21.03	18.49	37.94	35.40	32.28	29.74
51Cr			2.45	0.1	15.50	13.05	30.82	28.37	27.18	24.73
			2.92	0.01	14.53	11.61	22.59	19.67	12.79	9.87
			2.78	0.001	3.90	1.12	8.99	6.21	3.13	0.35
ADCC-014	PBMC	100	4.64	10	53.54	48.90	56.12	51.48	ND	ND
51Cr			4.64	1	46.84	42.20	43.00	38.36	ND	ND
			4.64	0.1	45.63	40.99	39.94	35.30	ND	ND
			4.64	0.01	7.73	3.09	9.79	5.15	ND	ND
			4.64	0.001	8.83	4.19	10.81	6.17	ND	ND
Average %lysis at 1 ug/ml concentration of mAbs						35.31		58.03		47.23
*The greater than 100% killing are due to incomplete killing by detergent used for 100% killing control.										

Example 9: CD40 Is Present on the Surface of NHL Cells from Lymph Node Biopsy Patients

NHL cells were isolated from biopsied lymph nodes from patients and were preserved in liquid nitrogen until use. Cell viability at the time of analysis exceeded 90%. The cells from two rituximab-sensitive and three rituximab-resistant patients (five patients in total) were stained with either a direct labeled 15B8-FITC or 15B8 plus anti-huIgG$_2$-FITC and analyzed by Flow cytometry. NHL cells from all the patients were found to express CD40. Table 10 shows that an average of 76% of NHL cells express CD40 (a range of 60-91%).

Table 10.

Patient ID [a]	Patient type [b]	% positive [c]	
		MS81 [d]	15B8 [e]
B	CR	n.d. [f]	91.02
J	CR	n.d.	60.36
H	NR	n.d.	85.08
H	NR	72.24	81.19
K	NR	n.d.	70.69
L	NR	n.d.	66.82

Average % positive *76*

[a] *NHL patients treated with anti-CD20 mAb*
[b] *patient response to anti- CD20 mAb; CR=complete responder; NR=nonresponder*
[c] *% of cells in lymphocyte gate that stain positive*
[d] *MS81, agonist anti-CD40 mAb*
[e] *15B8, antagonist anti-CD40 Mab*
[f] *n.d., not done*

Example 10: 5.9 and 12.12 Do Not Stimulate Proliferation of Cancer Cells from the Lymph Nodes of NHL Patients

CD40 ligand is known to provide a stimulatory signal for the survival and proliferation of lymphoma cells from NHL patients. Binding of some anti-CD40 antibodies (agonist) can provide a similar stimulatory signal for the proliferation of patient cancer cells. Antibodies with strong B cell stimulatory activity are not suitable candidate for therapeutic treatment of B cell lymphomas. The two candidate antibodies were tested for their ability to induce proliferation of NHL cells from 3 patients. The cells

`isolated from lymphnode (LN) biopsies were cultured with varying concentrations of candidate antibodies (range of 0.01 to 300 μg/ml) for a total of 3 days. The cell proliferation was measured by incorporation of tritiated thymidine. Neither of the two candidate mAbs induced any proliferation of cancer cells at any concentration tested (Table 11). Antibodies even in the presence of exogenously added IL-4, a B cell growth factor, did not induce proliferation of NHL cells (tested in one of the thee patient cells. These results indicate that 5.9 and 12.12 are not agonist anti-CD40 antibodies and do not stimulate proliferation *in vitro* of NHL cells from patients.

Table 11. Proliferation of cancer cells from LN of NHL patients in response to candidate anti-CD40 mAbs

		CPM		S. index	CPM	S. index	CPM	S. index
Donor#	**Abs conc(ug/ml)**	**Cells + IgG1**	**Cells +5.9**	**5.9**	**cells + 12.12**	**12.12**	**cells +MS81**	**MS81**
PP	0.01	180	203	1.23	133.67	0.74	ND	ND
	0.1	107.5	151.67	1.41	136	1.27	ND	ND
	1	130.67	206.67	1.58	197.33	1.51	179	1.37
	10	152.5	245	1.61	137.33	0.90	871.67	5.71
	100	137.67	332.33	2.41	157.33	1.14	ND	ND
	300	137.67	254.33	1.85	100.67	0.73	ND	ND
MM	0.01	165	180.33	1.09	124	0.75	ND	ND
	0.1	180.5	149.67	0.83	111.33	0.62	ND	ND
	1	62	109.67	1.77	104.67	1.69	ND	ND
	10	91.5	93.33	1.02	100	1.09	763	8.34
	100	123	173	1.41	105.33	0.86	ND	ND
	300	109	183.67	1.69	157	1.44	ND	ND
BD (IL-4)	0.01	1591.5	1623.67	1.02	1422	0.89	ND	ND
	0.1	1405	1281	0.91	1316.33	0.94	ND	ND
	1	1526	1352.33	0.89	1160	0.76	1508.33	0.99
	10	1450	1424	0.98	1244	0.86	4146.67	2.86
	100	1406.67	1497.67	1.06	1255.33	0.89	ND	ND
	300	1410.33	1466.67	1.04	1233	0.87	ND	ND

<u>Example 11: 5.9 and 12.12 Can Block CD40 Ligand-Mediated Proliferation of Cancer Cells from Non-Hodgkin's Lymphoma Patients</u>

Engagement of CD40 by CD40 ligand induces proliferation of cancer cells from NHL patients. An antagonistic anti-CD40 antibody is expected to inhibit this

proliferation. The two candidate anti-CD40 antibodies were tested at varying concentrations (0.01 μg /ml to 100 μg /ml) for their ability to inhibit CD40 ligand-induced proliferation of NHL cells from patients. NHL cells from patients were cultured in suspension over CD40L-expressing feeder in the presence of IL-4. The NHL cell proliferation was measured by ^{3}H-thymidine incorporation. Both antibodies were found to be very effective for inhibiting CD40 ligand-induced proliferation of NHL cells (Table 12, n=2). Nearly complete inhibition of CD40 ligand-induced proliferation could be achieved at 1.0 to 10 μg/ml concentration of antibodies.

Table 12. Inhibition of CD40 ligand-induced proliferation of cancer cells from the LN of NHL patients.

Patient	Abs Conc (ug/ml)	CPM IgG1	5.9 CPM	5.9 % inhibition	12.12 CPM	12.12 % inhibition	Rituximab CPM	Rituximab % inhibition
BD	0.01	29525.5	25369	14	24793	16	29490.3	0
	0.1	29554	20265.33	31	13671	54	29832.7	-1
	1	29486.67	6785.33	77	453	98	26355.3	11
	10	29710	506.33	98	371	99	29427.3	1
	100	29372.33	512.33	98	386.67	99	ND	ND
PP	0.01	23572	23229.33	1	23666	0	25317.3	-7
	0.1	22520	19092.33	15	17197	24	26349.7	-17
	1	23535.67	1442.33	94	802.67	97	26515.7	-13
	10	23101.5	608.67	97	221.33	99	25478.3	-10
	100	23847.33	ND	ND	252	99	ND	ND

% inhibition: 100-(CPM with test Abs/CPM with control mAb) *100%

Example 12: Effect of 5.9 on Number of Viable NHL Cells When Cultured with CD40-Ligand Bearing Cells

Effects of 5.9 on the viable NHL cell numbers when cultured with CD40-ligand bearing cells over an extended period of time (days 7, 10, and 14) were investigated. CD40 ligand-mediated signaling through CD40 is important for B cell survival. This set of experiments evaluated the effect of anti-CD40 antibodies on NHL cell numbers at days 7, 10, and 14. NHL cells from five patients were cultured in suspension over CD40L-expressing irradiated feeder cells in the presence of IL-4. The control human IgG and 5.9 antibodies were added at concentrations of 10 μg/ml at day 0 and day 7. The viable cells under each condition were counted on the specified day. Cell numbers in the control

group (IgG) increased with time as expected. Reduced numbers of cells were recovered from 5.9-treated cultures compared to control group. The greatest levels of reduction in cell numbers by 5.9 antibody were observed at day 14 and were on average 80.5% (a range of 49-94%) compared to isotype control (n=5). These data are summarized in Table 13.

Table 13. Effect of anti-CD40 antibody (5.9/5.11) on NHL patient cell numbers over prolonged culture period (day 7, 10, and 14)

Patient	Days in culture	Viable cell numbers		% reduction compared to IgG control
		IgG	mAb 5.9/5.11	
PS	0	1000000	1000000	**0.00**
	7	935000	447500	**52.14**
	10	1270900	504100	**60.34**
	14	1029100	525000	**48.98**
MT	0	1000000	1000000	**0.00**
	7	267600	182500	**31.80**
	10	683400	191600	**71.96**
	14	1450000	225000	**84.48**
BRF	0	250000	250000	**0.00**
	7	145000	86667	**40.23**
	10	207500	65000	**68.67**
	14	570500	33330	**94.16**
DP	0	250000	250000	**0.00**
	7	188330	136670	**27.43**
	10	235000	128330	**45.39**
	14	428330	58330	**86.38**
PP	0	250000	250000	**0.00**
	7	270000	176670	**34.57**
	10	311670	128330	**58.83**
	14	458330	53330	**88.36**

* % reduction compare to ctrl Abs=100-(test Abs/ctrl Abs)*100

<u>Example 13: 5.9 and 12.12 Are Able to Kill Cancer Cells from the Lymph Nodes of NHL Patients by ADCC</u>

Both 5.9 and 12.12 are fully human antibodies of IgG_1 isotype and were shown to induce the killing of lymphoma cell lines *in vitro* by the mechanism of ADCC (Table 9). They were tested for their ability to kill cancer cells from a single NHL patient in *in vitro* assays. Enriched NK cells from normal volunteer donor either fresh after isolation or

after culturing overnight at 37°C were used as effector cells in this assay. Similar results were obtained with both freshly isolated NK cells and NK cells used after overnight culture. The higher level of ADCC was observed with 12.12 compared with 5.9 against the NHL cells from the patient. NHL cells also express CD20, the target antigen for rituximab (Rituxan®), which allowed for comparison of the ADCC activity of these two candidate mAbs with rituximab. Antibody 12.12 and rituximab show similar level of ADCC activity with 5.9 scoring lower in this assay. These data are shown in Figures 4A and 4B.

Example 14: 5.9 and 12.12 Can Block CD40-Mediated Survival and Proliferation of Cancer Cells from CLL Patients

The candidate antibodies can block CD40-mediated survival and proliferation of cancer cells from CLL patients. CLL cells from patients were cultured in suspension over CD40L-expressing formaldehyde-fixed CHO cells under two different conditions: addition of human isotype antibody IgG (control); and addition of either 5.9 or 12.12 monoclonal antibody. All antibodies were added at concentrations of 1, 10, and 100 μg/mL in the absence of IL-4. The cell counts were performed at 24 and 48 h by MTS assay. Reduced numbers of cells were recovered from 5.9- (n=6) and 12.12- (n=2) treated cultures compared to control group. The greater differences in cell numbers between anti-CD40 mAb-treated and control antibody-treated cultures were seen at the 48-h time point. These data are summarized in Table 14.

Table 14. The effect of candidate antibodies on CD40-induced survival and proliferation of cancer cells from CLL patients measured at 48 h after the culture initiation

Patient#	Ab conc(μg/ml)	Relative cell numbers			% reduction in cell numbers*	
		IgG1	5.9/5.11	12.12	5.9/5.11	12.12
1	1	269.31	25.27	ND	90.62	ND
	10	101.58	33.07	ND	67.44	ND
	100	130.71	40.16	ND	69.28	ND
2	1	265.55	75.8	ND	71.46	ND
	10	227.57	128.5	ND	43.53	ND
	100	265.99	6.4	ND	97.59	ND
3	1	85.9	35.39	ND	58.80	ND
	10	70.44	39.51	ND	43.91	ND
	100	77.65	20.95	ND	73.02	ND
4	1	80.48	15.03	ND	81.32	ND
	10	63.01	19.51	ND	69.04	ND
	100	55.69	3.65	ND	93.45	ND
5	1	90.63	91.66	89.59	-1.14	1.15
	10	78.13	82.28	60.41	-5.31	22.68
	100	63.53	86.47	39.59	-36.11	37.68
6	1	130.21	77.6	71.88	40.40	44.80
	10	131.77	78.13	73.96	40.71	43.87
	100	127.08	76.56	82.29	39.75	35.25

* % reduction compared to control Abs=100-(test Abs/control Abs)*100

Example 15: 5.9 and 12.12 Show Anti-Tumor Activity in Animal Models

Pharmacology/in vivo efficacy

The candidate mAbs are expected to produce desired pharmacological effects to reduce tumor burden by either/both of two anti-tumor mechanisms, blockade of proliferation/survival signal and induction of ADCC. The currently available xenograft human lymphoma models use long-term lymphoma cell lines that, in contrast to primary cancer cells, do not depend on CD40 stimulation for their growth and survival. Therefore the component of these mAbs' anti-tumor activity based on blocking the tumor proliferation/survival signal is not expected to contribute to anti-tumor efficacy in these models. The efficacy in these models is dependent on the ADCC, the second anti-tumor mechanism associated with the 5.9 and 12.12 mAbs. Two xenograft human lymphoma models based on Namalwa and Daudi cell lines were assessed for anti-tumor activities of

candidate mAbs. To further demonstrate their therapeutic activity, these candidate mAbs were evaluated in an unstaged and staged xenograft human lymphoma model based on the Daudi cell line.

Summary of in vivo efficacy data

When administered intraperitoneally (i.p.) once a week for a total of 3 doses, 12.12, one of the two candidate mAbs, significantly inhibited the growth of aggressive unstaged B cell lymphoma (Namalwa) in a dose-dependent manner (Figure 5). The second candidate mAb, 5.9, was tested only at a single dose in this study and was less effective than 12.12 at the same dose. Interestingly, 12.12 was found to be more efficacious in this model than rituximab. It is possible that lower efficacy by rituximab could be due to low CD20 expression on the Namalwa lymphoma cell line. The efficacy observed with candidate mAbs has greater importance because only one of the two cancer cell killing mechanisms (ADCC) is operative in the current xenograft lymphoma model. Two killing mechanisms, ADCC and blocking of survival signal, are expected to contribute to anti-tumor activities in human lymphoma patients. This is likely to increase the chance of achieving efficacy in human lymphoma patients. The candidate anti-CD40 mAbs also showed a trend toward tumor growth inhibition in a second B cell lymphoma model (non-validated Daudi model, data not shown). In follow-up studies, the two candidate antibodies were shown to have dose-dependent anti-tumor efficacy in both the unstaged and staged Daudi lymphoma models (Figures 6 and 7, respectively). In the staged Daudi model, the 12.12 mAb was more efficacious at reducing tumor volume than was a similar dose of Rituxan®.

Xenograft human B cell Lymphoma models

To ensure consistent tumor growth, T cell-deficient nude mice were whole-body irradiated at 3 Gy to further suppress the immune system one day before tumor inoculation. Tumor cells were inoculated subcutaneously in the right flank at 5×10^6 cells per mouse. Treatment was initiated either one day after tumor implantation (unstaged subcutaneous xenograft human B cell lymphoma models, Namalwa and Daudi) or when tumor volume reached 200-400 mm^3 (staged Daudi model, usually 15 days after tumor

inoculation). Tumor-bearing mice were injected anti-CD40 mAbs intraperitoneally (i.p.) once a week at the indicated doses. Tumor volumes were recorded twice a week. When tumor volume in any group reached 2500 mm^3, the study was terminated. Data were analyzed using ANOVA or Kruskal-Wallis test and corresponding post-test for multi-group comparison.

In the unstaged Namalwa model, anti-CD40 mAb12.12, but not Rituxan® (rituximab), significantly ($p= <0.01$) inhibited the growth of Namalwa tumors (tumor volume reduction of 60% versus 25% for rituxamab, n=10 mice/group) (Figure 5). Thus, in this model, anti-CD40 mAb 12.12 was more potent than rituximab. It is noteworthy that the second candidate mAb, 5.9, was at least as efficacious as rituximab at a dose $1/10^{th}$ that of rituximab. Both anti-CD40 mAb 12.12 and rituxan significantly prevented tumor development in the unstaged Daudi tumor model (14/15 resistance to tumor challenge) (Figure 6).

When these anti-CD40 monoclonal antibodies were further compared in a staged xenograft Daudi model, in which treatment started when the subcutaneous tumor was palpable, anti-CD40 mAb 12.12 at 1 mg/kg caused significant tumor reduction ($p=0.003$) with 60% complete regression (6/10), while rituximab at the same dose did not significantly inhibit the tumor growth nor did it cause complete regression.

In summary, the anti-CD40 mAb 12.12 significantly inhibited tumor growth in experimental lymphoma models. At the same dose and regimen, mAb 12.12 showed better anti-cancer activity than did Rituxan® (rituximab). Further, no clinical sign of toxicity was observed at this dose and regimen. These data suggest that the anti-CD40 mAb 12.12 has potent anti-human lymphoma activity *in vitro* and in xenograft models and could be clinically effective for the treatment of lymphoma.

Example 16: Pharmacokinetics of 5.9 and 12.12

The pharmacokinetics of anti-CD40 mAb in mice was studied after single IV and IP dose administration. Anti-CD40 mAb exhibited high systemic bioavailability after IP administration, and prolonged terminal half-life (>5 days) (data not shown). This pilot study was conducted to aid in the design of pharmacology studies; however, it is of little

to no importance for the development activity of this mAb since this fully human mAb does not cross react with mouse CD40.

Example 17: Characterization of Epitope for Monoclonal Antibodies 12.12 and 5.9

To determine the location of the epitope on CD40 recognized by monoclonal antibodies 12.12 and 5.9, SDS-PAGE and Western blot analysis were performed. Purified CD40 (0.5 μg) was separated on a 4-12% NUPAGE gel under reducing and non-reducing conditions, transferred to PVDF membranes, and probed with monoclonal antibodies at 10 μg/ml concentration. Blots were probed with alkaline phosphatase conjugated anti-human IgG and developed using the Western Blue[R] stabilized substrate for alkaline phosphatase (Promega).

Results indicate that anti-CD40 monoclonal antibody 12.12 recognizes epitopes on both the non-reduced and reduced forms of CD40, with the non-reduced form of CD40 exhibiting greater intensity than the reduced form of CD40 (Table 15; blots not shown). The fact that recognition was positive for both forms of CD40 indicates that this antibody interacts with a conformational epitope part of which is a linear sequence. Monoclonal antibody 5.9 primarily recognizes the non-reduced form of CD40 suggesting that this antibody interacts with a primarily conformational epitope (Table 15; blots not shown).

Table 15. Domain identification.

	Domain 1	Domain 2	Domain 3	Domain 4
mAb 12.12	-	+	-	-
mAb 5.9	-	+	-	-
mAb 15B8	+	-	-	-

To map the antigenic region on CD40, the four extracellular domains of CD40 were cloned and expressed in insect cells as GST fusion proteins. The secretion of the four domains was ensured with a GP67 secretion signal. Insect cell supernatant was analyzed by SDS-PAGE and western blot analysis to identify the domain containing the epitope.

Monoclonal antibody 12.12 recognizes an epitope on Domain 2 under both reducing and non-reducing conditions (Table 16; blots not shown). In contrast, monoclonal antibody 5.9 exhibits very weak recognition to Domain 2 (Table 16; blots not shown). Neither of these antibodies recognize Domains 1, 3, or 4 in this analysis.

Table 16. Domain 2 analysis.

	Reduced	Non-reduced
mAb 12.12	++	+++
mAb 5.9	+	+

To define more precisely the epitope recognized by mAb 12.12, peptides were synthesized from the extracellular Domain 2 of CD40, which corresponds to the sequence PCGESEFLDTWNRETHCHQHKYCDPNLGLRVQQKGTSETDTICT (residues 61-104 of the sequence shown in Fig. 13B). SPOTs membranes (Sigma) containing thirty-five 10mer peptides with a 1-amino-acid offset were generated. Western blot analysis with mAb 12.12 and anti-human IgG beta-galactosidase as secondary antibody was performed. The blot was stripped and reprobed with mAb 5.9 to determine the region recognized by this antibody

SPOTs analysis probing with anti-CD40 monoclonal antibody 12.12 at 10 μg/ml yielded positive reactions with spots 18 through 22. The sequence region covered by these peptides is shown in Table 17.

Table 17. Results of SPOTs analysis probing with anti-CD40 monoclonal antibody 12.12.

Spot Number	Sequence Region
18	HQHKYCDPNL (residues 78-87 of Fig. 13B)
19	QHKYCDPNLG (residues 79-88 of Fig. 13B)
20	HKYCDPNLGL (residues 80-89 of Fig. 13B)
21	KYCDPNLGLR (residues 81-90 of Fig. 13B)
22	YCDPNLGLRV (residues 82-91 of Fig. 13B)

These results correspond to a linear epitope of: YCDPNL (residues 82-87 of the sequence shown in Fig. 13B). This epitope contains Y82, D84, and N86, which have been predicted to be involved in the CD40-CD40 ligand interaction.

SPOTs analysis with mAb 5.9 showed a weak recognition of peptides represented by spots 20-22 shown in Table 18, suggesting involvement of the region YCDPNLGL (residues 82-89 of the sequence shown in Fig. 13B) in its binding to CD40. It should be noted that the mAbs 12.12 and 5.9 compete with each other for binding to CD40 in BIACORE analysis.

Table 18. Results of SPOTs analysis probing with anti-CD40 monoclonal antibody 5.9.

Spot Number	Sequence Region
20	HKYCDPNLGL (residues 80-89 of Fig. 13B)
21	KYCDPNLGLR (residues 81-90 of Fig. 13B)
22	YCDPNLGLRV (residues 82-91 of Fig. 13B)

The linear epitopes identified by the SPOTs analyses are within the CD40 B1 module. The sequence of the CD40 B1 module is: HKYCDPNLGLRVQQKGTSETDTIC (residues 80-103 of Fig. 13B).

Within the linear epitope identified for 12.12 is C83. It is known that this cysteine residue forms a disulphide bond with C103. It is likely that the conformational epitope of the 12.12 mAb contains this disulfide bond (C83-C103) and/or surrounding amino acids conformationally close to C103.

Example 18: Number of CD20 and CD40 Molecules on Namalwa and Daudi Cells

The number of CD20 and CD40 molecules on Namalwa and Daudi cells was determined as outlined in Figure 8, using antibody concentrations of 0.01, 0.1, 1, 10, and 100 μg/ml. As can be seen in Figure 8, the average number of CD20 molecules (target for rituximab) is greater on both the Namalwa and Daudi cell lines than is the number of CD40 molecules (target for mAb 12.12).

Example 19: ADCC of mAb 12.12 and Rituximab Against Daudi Lymphoma Cells

The rituximab and candidate mAb 12.12 were tested *in vitro* for ADCC activity at variable concentrations against lymphoma cell line Daudi as target cells and purified NK cells from healthy human volunteers as effector cells (Figure 9). The maximum specific lysis of target lymphoma cells induced by anti-CD40 mAb was greater compared to the lysis induced by rituximab (75% versus 57 %, n=3, p=0.02). In addition, ED50 for rituximab was on average 11.1 (±5.0)-fold higher (n=3) than ED50 for anti-CD40 for this activity.

Example 20: Agonistic and Antagonistic Activity Against Primary Cancer Cell from NHL, CLL, and NM Patients

In collaboration with clinical investigators, the candidate mAbs is tested for a variety of activities (listed below) against primary cancer cells from NHL and CLL and multiple myeloma patients.

- Agonistic effect in proliferation assays (8 NHL patients, 8 CLL patients and 8 MM patients)
- Antagonistic effect in proliferation assays (8 NHL patients, 8 CLL patients and 8 MM patients)

- Apoptotic effect by Annexin V assay (3-4 NHL patients, 4 CLL patients, and 4 MM patients)
- Reversing survival signal by Annexin V assay (3 NHL patients, 3 CLL patients and 3 MM patients)
- Complement dependent cytotoxicity (4 NHL patients, 4 CLL patients and 4MM patients)
- Antibody dependent cytotoxicity (6 NHL patients, 6 CLL patients and 6 MM patients)

Example 21: Identification of Relevant Animal Species for Toxicity Studies

As these two candidate antibodies do not cross-react with rodent CD40, other species must be identified for testing toxicologic effects.

The ability of the two candidate anti-CD40 antibodies to cross-react with animal CD40 is tested by flow cytometric assays. Rat, rabbit, dog, cynomolgous monkeys and marmoset monkeys are tested for this study.

The candidate antibodies show antagonistic activity upon binding to CD40 on human B cells. To identify an animal species that has similar response to candidate antibodies, lymphocytes from species that show binding to candidate antibodies are tested in proliferation assays for antagonistic activity. The lymphocytes from the species selected for antagonistic binding of candidate antibodies are further tested for their ability to serve as effector cells for killing CD40-expressing lymphoma cell lines through the mechanism of ADCC. Finally the selected animal species are tested in an IHC study for the tissue-binding pattern of candidate antibodies. The animal species responding to the candidate antibodies in these assays in a manner similar to that observed for human cells are chosen for toxicology studies.

Initial studies indicate that the candidate anti-CD40 mAbs cross-react with cynomolgous monkey CD40.

Example 22: Tumor Targeting Profile of 5.9 and 12.12

To determine the relative tumor targeting profile of 12.12 and 5.9 mAbs, fluorescent-labeled candidate mAbs and isotype control antibodies are administered into

tumor-bearing mice. Tumor specimens and normal organs are harvested at different time points after dosing. The accumulation of labeled antibody in tumors and normal organs is analyzed.

Example 23: Mechanism of Action of 5.9 and 12.12

To elucidate the mechanism(s) that mediates the tumor growth inhibition by the 5.9 and 12.12 mAbs, the following studies are undertaken:

Fc-receptor knock-out or blockage model: ADCC is mediated by binding of effecter cells such as NK, marcrophage, and monocytes to the Fc portion of antibody through Fc receptor. Mice deficient in activating Fc receptors as well as antibodies engineered to disrupt Fc binding to those receptors will block the ADCC mediated tumor growth inhibition. Loss or significantly reduced tumor inhibition in this model will suggest that the tumor growth inhibition by these two candidate mAbs is mainly mediated by ADCC mechanism.

Example 24: Clinical Studies with 5.9 and 12.12

Clinical Objectives

The overall objective is to provide an effective therapy for B cell tumors by targeting them with an anti-CD40 IgG1. These tumors include B-cell lymphoma, Chronic Lymphocytic Lyphoma (CLL), Acute Lymphoblastic Leukemia (ALL), Multiple Myeloma (MM), Waldenstrom's Macroglobulinemia, and Systemic Castleman's Disease. The signal for these diseases is determined in phase II although some measure of activity may be obtained in phase I. Initially the agent is studied as a single agent, but will be combined with other agents, chemotherapeutics, and other antibodies, as development proceeds.

Phase I

- Evaluate safety and pharmacokinetics – dose escalation in subjects with B cell malignancies.

- Choose dose based on safety, tolerability, and change in serum markers of CD40. In general an MTD is sought but other indications of efficacy (depletion of CD40+ B cells, etc.) may be adequate for dose finding.
- Consideration of more than one dose especially for different indications, e.g., the CLL dose may be different than the NHL. Thus, some dose finding may be necessary in phase II.
- Patients are dosed weekly with real-time pharmacokinetic (Pk) sampling. Initially a 4-week cycle is the maximum dosing allowed. The Pk may be highly variable depending on the disease studied, density of CD40 etc.
- This trial(s) is open to subjects with B-cell lymphoma, CLL, and potentially other B cell malignancies.
- Decision to discontinue or continue studies is based on safety, dose, and preliminary evidence of anti-tumor activity.
- Activity of drug as determined by response rate is determined in Phase II.
- Identify dose(s) for Phase II.

Phase II

Several trials will be initiated in the above-mentioned tumor types with concentration on B-cell lymphoma, CLL, and Multiple Myeloma (MM). Separate trials may be required in low grade and intermediate/high grade NHL as CD40 may have a different function depending on the grade of lymphoma. In low-grade disease, CD40 acts more as a survival factor, preventing apoptosis. In higher-grade disease, interruption of CD40 signaling may lead to cell death. More than one dose, and more than one schedule may be tested in a randomized phase II setting.

In each disease, target a population that has failed current standard of care:

- CLL: patients who were resistant to Campath® and chemotherapy.
- Low grade NHL: Rituxan® or CHOP-R failures
- Intermediate NHL: CHOP-R failures
- Multiple Myeloma: Chemotherapy failures

- ✓ Decision to discontinue or continue with study is based on proof of therapeutic concept in Phase II
- ✓ Determine whether surrogate marker can be used as early indication of clinical efficacy
- ✓ Identify doses for Phase III

Phase III

Phase III will depend on where the signal is detected in phase II, and what competing therapies are considered to be the standard. If the signal is in a stage of disease where there is no standard of therapy, then a single arm, well-controlled study could serve as a pivotal trial. If there are competing agents that are considered standard, then head-to-head studies are conducted.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

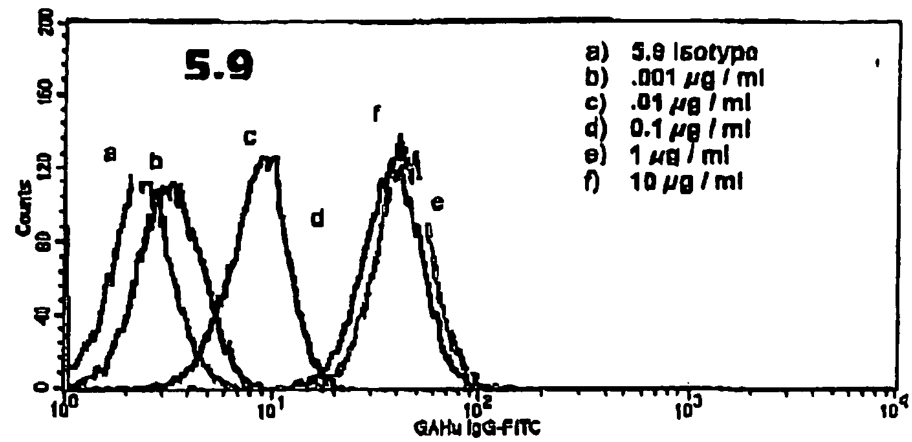
All publications and patent applications mentioned in the specification are indicative of the level of those skilled in the art to which this invention pertains. All publications and patent applications are herein incorporated by reference to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference.

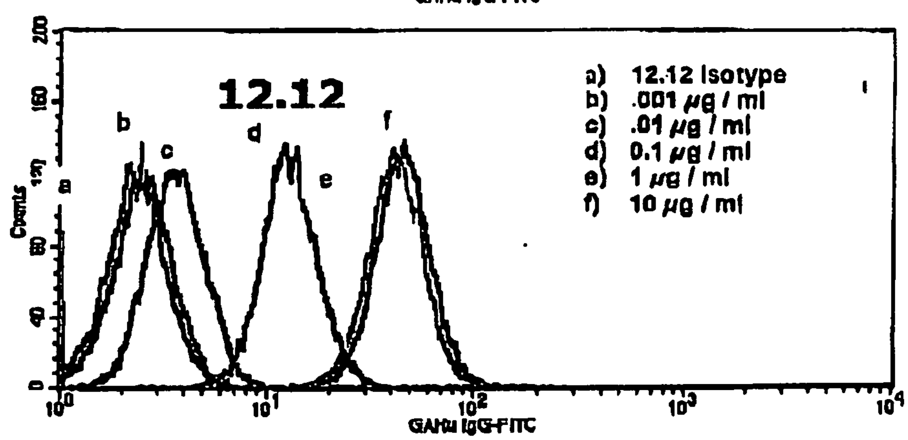
ANTAGONIST ANTI-CD40 MONOCLONAL ANTIBODIES AND METHODS FOR THEIR USE

ABSTRACT OF THE DISCLOSURE

Methods of therapy for treating diseases mediated by stimulation of CD40 signaling on CD40-expressing cells are provided. The methods comprise administering a therapeutically effective amount of an antagonist anti-CD40 antibody or antigen-binding fragment thereof to a patient in need thereof. The antagonist anti-CD40 antibody or antigen-binding fragment thereof is free of significant agonist activity, but exhibits antagonist activity when the antibody binds a CD40 antigen on a human CD40-expressing cell. Antagonist activity of the anti-CD40 antibody or antigen-binding fragment thereof beneficially inhibits proliferation and/or differentiation of human CD40-expressing cells, such as B cells.

FIG. 1A





Fluorescence intensity

FIG. 1B

Heavy Chain

	Frm1	CDR1	Frm2	CDR2
F5.9	QVQLEQESAEVKKPGESLKISCKGSGYSFT	SYWIG	WVRQMPGKGLEWMG	IIYPGDSDTRYSPSFQG
12.12	QVQLEDSGGGVVQPGRSLRLSCAASGFTF	SSYGM	HWVRQAPGKGLEWVAV	ISYEESNRYHADSVKGR
15B8	QVQLQESGGGVVQPGRSLRLSCAASGFTFN	NFGIH	WVRQAPGKGLEWVA	VISYDGSDKYYADSVKG

	Frm3	CDR3	Frm4
F5.9	QVTISADKSISTAYLQWSSLKASDTAMYYCAR	GTAAGRDYYYYYGMDV	WGQGTTVTVSS
12.12	FTISRDNSKITLYLQMNSLRTEDTAVYYCAR	DGGIAAPGPDY	WGQGTLVTVSS
15b8	RFTISRDNSKNTLNLQMNSLRAEDTAVYYCAR	DRRYYYHYYGM DV	WGQGTMVTVSS

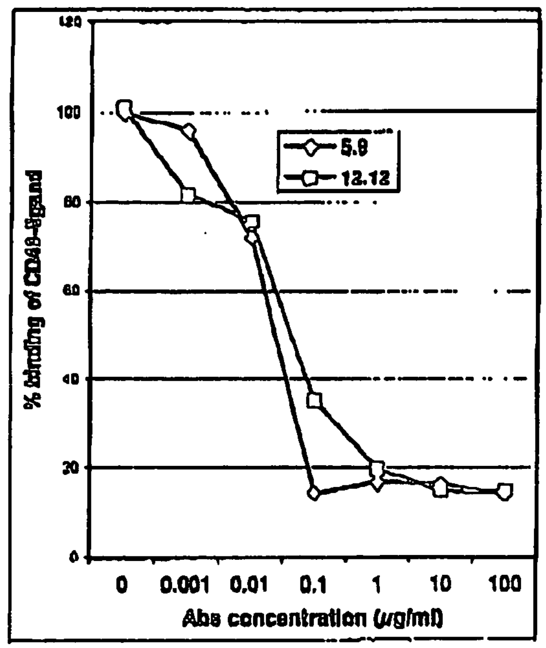
FIG. 2A

Light Chain

	Frm1	CDR1	Frm2	CDR2
F5.9	DIQLTQSPLSSPVTLGQPASISC	RSSQSL NTYLN	WLQQRPGQPPRLLIY	KFFRRLS
12.12	ETQLTQSPGTLSLSPGERVTLSC	RASQIF SSNSLA	WYQNKSGQAPRLLIY	GASSRAT
15b8	DIVMTQSPLSLSVAPGQPASISC	KSSQSLLESYGETYLY	WYLQKPGQPPQLLIY	AVFKRFS

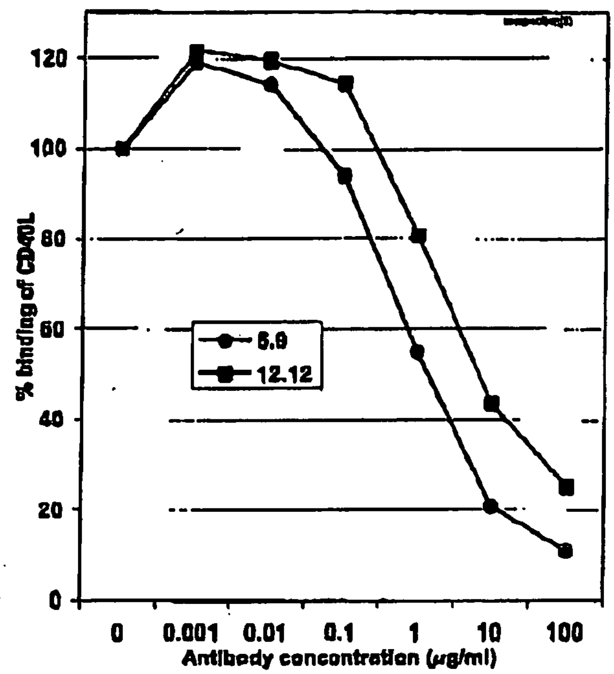
	Frm3	CDR3	Frm4
F5.9	GVPDRFSGSGAGTDFTLKISRVEAEDVGVYYC	MQVTQFPHT	FGQGTRLEIK
12.12	DFPDRFSGSGSGTDFTLTVTNLEPEDFCSA	LSAVWYSLT	FGGGTKVEIK
15b8	GVPDRFSGSGSGTDFTLKISRVEAEDVGVYYC	MQSMQLPLT	FGGGTKVEIK

FIG. 2B



% binding of CD48-ligand
120
100
80
60
40
20
0
5.9
12.12
0
0.001
0.01
0.1
1
10
100
Abs concentration (µg/ml)

FIG. 3A



120
100
80
60
40
20
0
% binding of CD40L
5.9
12.12
0
0.001
0.01
0.1
1
10
100
Antibody concentration (μg/ml)

FIG. 3B

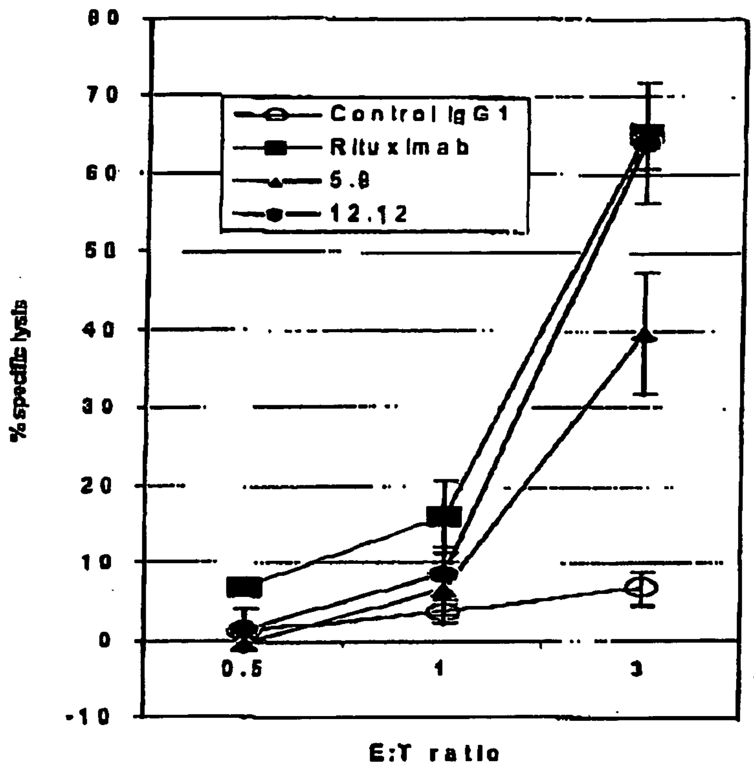
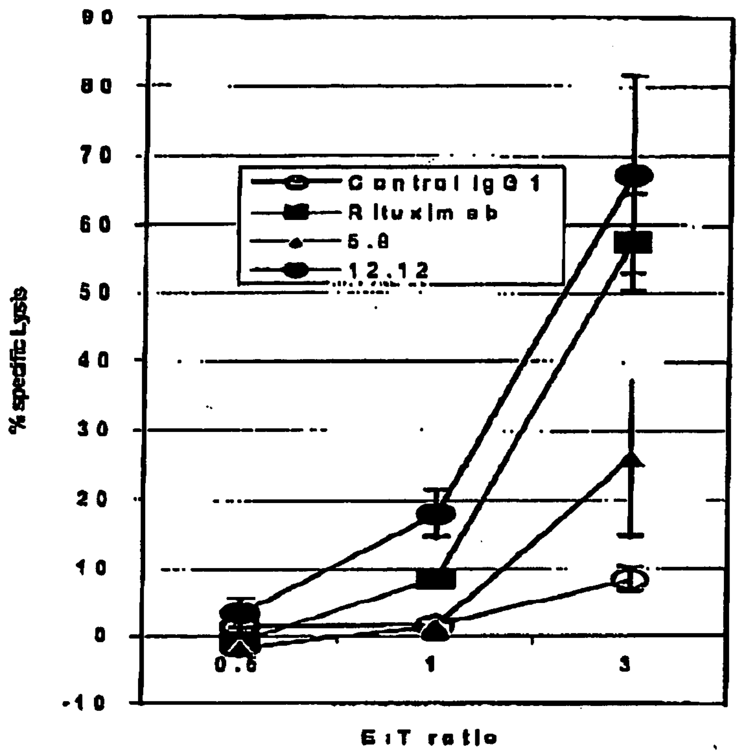
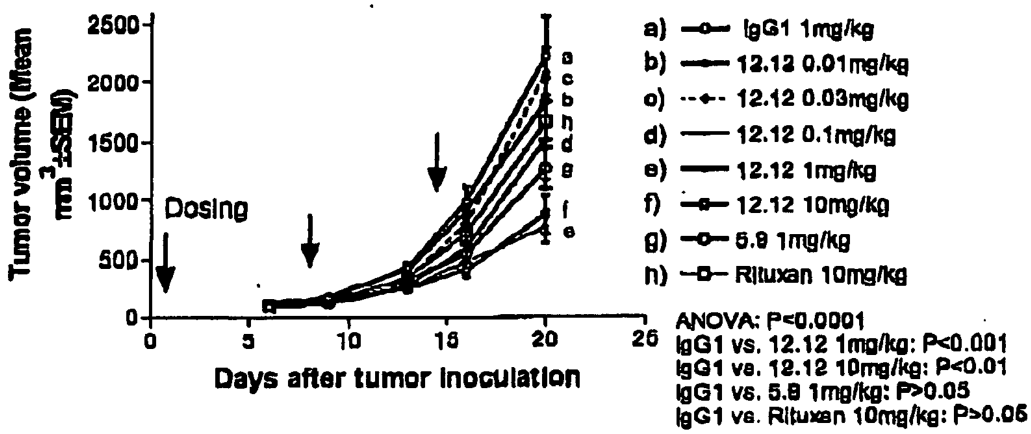

80
70
60
50
40
30
20
10
0
-10
% specific lysis
Control IgG1
Rituximab
5.8
12.12
0.5
1
3
E:T ratio

FIG. 4A



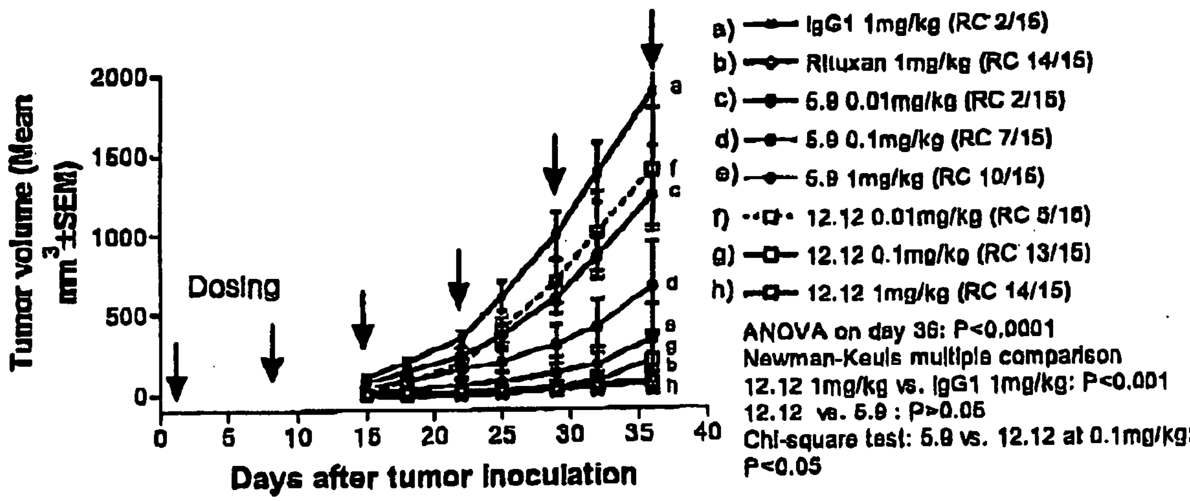
90
80
70
60
50
40
30
20
10
0
-10
% specific Lysis
Control IgG1
Rituximab
5.8
12.12
0.5
1
3
E:T ratio

FIG. 4B



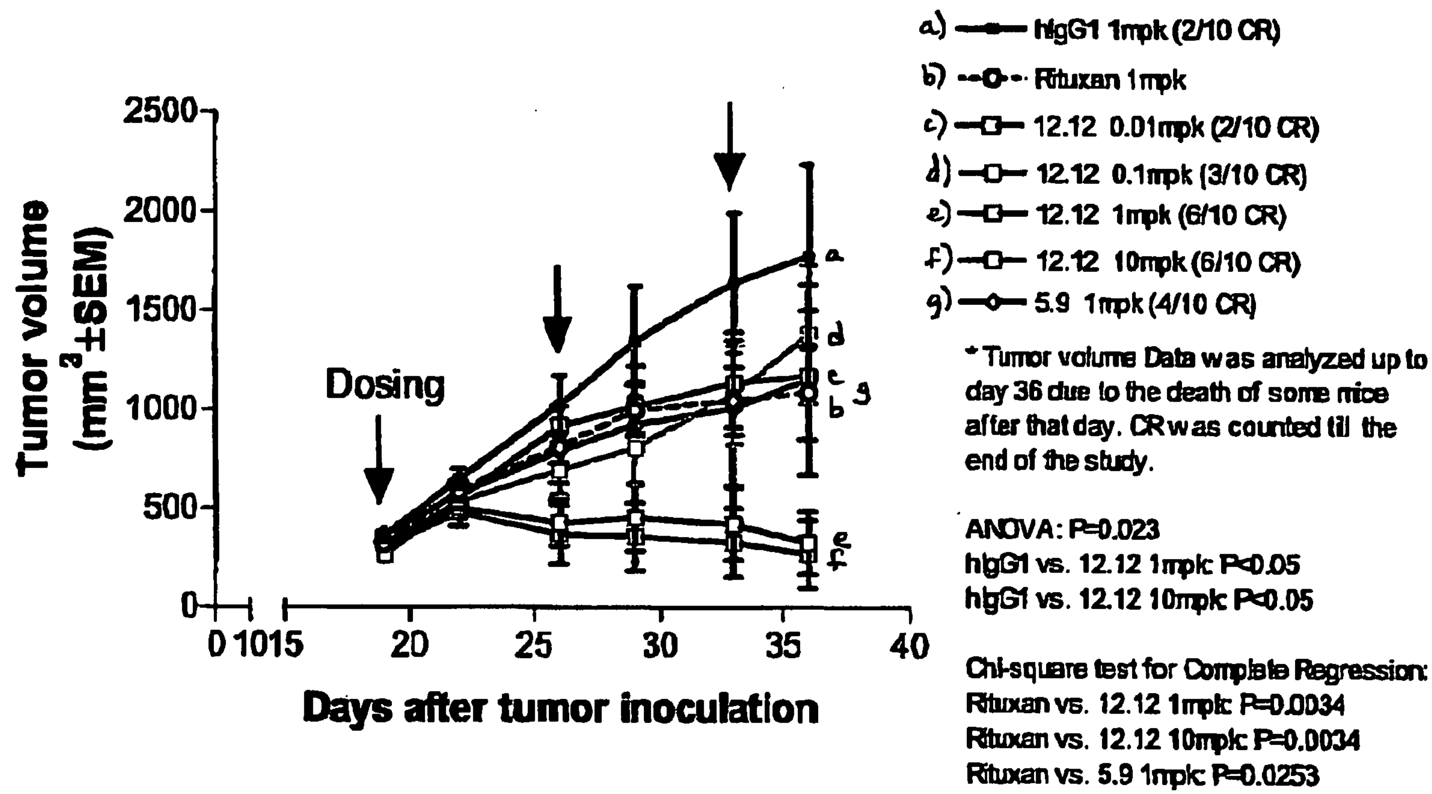
Tumor volume (Mean mm3 ±SEM)
2500
2000
1500
1000
500
0
Dosing
0
5
10
15
20
25
Days after tumor inoculation
a
c
b
h
d
g
f
e
a) IgG1 1mg/kg
b) 12.12 0.01mg/kg
c) 12.12 0.03mg/kg
d) 12.12 0.1mg/kg
e) 12.12 1mg/kg
f) 12.12 10mg/kg
g) 5.9 1mg/kg
h) Rituxan 10mg/kg
ANOVA: P<0.0001
IgG1 vs. 12.12 1mg/kg: P<0.001
IgG1 vs. 12.12 10mg/kg: P<0.01
IgG1 vs. 5.9 1mg/kg: P>0.05
IgG1 vs. Rituxan 10mg/kg: P>0.05

FIG. 5



Tumor volume (Mean mm3 ±SEM)
2000
1500
1000
500
0
Dosing
0
5
10
15
20
25
30
35
40
Days after tumor inoculation
a
f
c
d
e
g
b
h
a) IgG1 1mg/kg (RC 2/15)
b) Rituxan 1mg/kg (RC 14/15)
c) 5.9 0.01mg/kg (RC 2/15)
d) 5.9 0.1mg/kg (RC 7/15)
e) 5.9 1mg/kg (RC 10/15)
f) 12.12 0.01mg/kg (RC 5/15)
g) 12.12 0.1mg/kg (RC 13/15)
h) 12.12 1mg/kg (RC 14/15)
ANOVA on day 36: P<0.0001
Newman-Keuls multiple comparison
12.12 1mg/kg vs. IgG1 1mg/kg: P<0.001
12.12 vs. 5.9 : P>0.05
Chi-square test: 5.9 vs. 12.12 at 0.1mg/kg:
P<0.05

FIG. 6



Tumor volume (mm³±SEM)
2500
2000
1500
1000
500
0
0 1015
20
25
30
35
40
Days after tumor inoculation
Dosing
a
d
c
b
g
e
f
a) hIgG1 1mpk (2/10 CR)
b) Rituxan 1mpk
c) 12.12 0.01mpk (2/10 CR)
d) 12.12 0.1mpk (3/10 CR)
e) 12.12 1mpk (6/10 CR)
f) 12.12 10mpk (6/10 CR)
g) 5.9 1mpk (4/10 CR)
* Tumor volume Data was analyzed up to day 36 due to the death of some mice after that day. CR was counted till the end of the study.
ANOVA: P=0.023
hIgG1 vs. 12.12 1mpk: P<0.05
hIgG1 vs. 12.12 10mpk: P<0.05
Chi-square test for Complete Regression:
Rituxan vs. 12.12 1mpk: P=0.0034
Rituxan vs. 12.12 10mpk: P=0.0034
Rituxan vs. 5.9 1mpk: P=0.0253

FIG. 7

Number of CD20 and CD40 Molecules on Namalwa and Daudii Cells

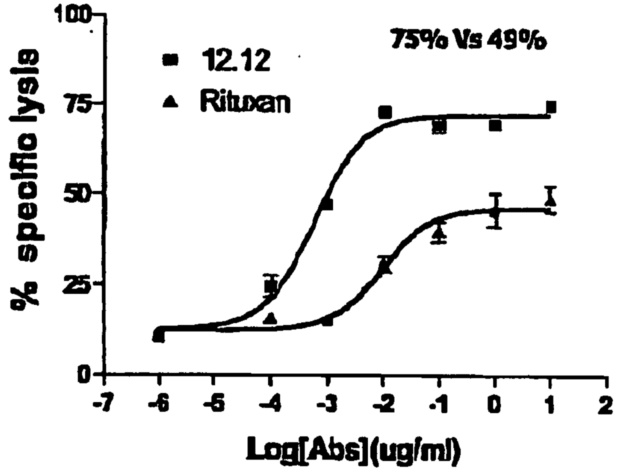
Methods:

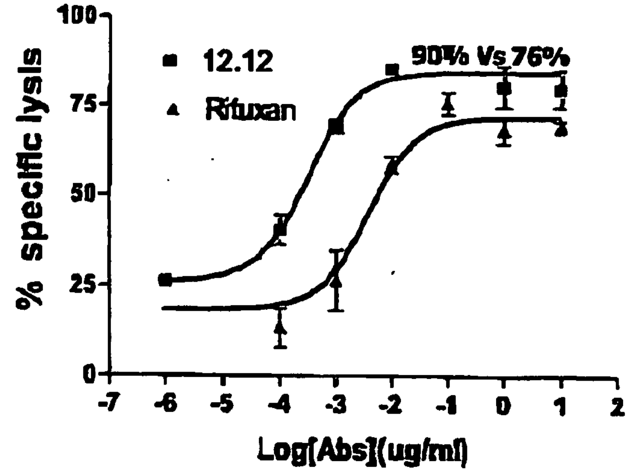
1. Harvest and wash cells once with PBS w/o Ca++/Mg++ plus 0.5%BSA and 0.1% Sodium Azide.
2. Block 1e5 cells with 10% huSerum in PBS w/o Ca++/Mg++ plus 0.1% Sodium Azide on ice for 30 minutes.
3. Stain cells with FITC conjugated antibodies (12.12-FITC or Rituximab-FITC) on ice for 40minutes. Cells were also stained with huIgG1-FITC for non-specific binding control. Antibody concentrations were 0.01, 0.1, 1, 10 and 100ug per mL
4. Determine Mean Channel Fluorescence (Geometric Mean) by flow cytometer using log amplifier. PI was added to exclude dead cells.
5. Determine Mean Channel Fluorescence (Geometric Means) of Quantum™24FITC (3,000 to 5,000 MESF*), QuantumTM25FITC (50,000 to 2,000,000 MESF) and Quantum™26FITC (10,000 to 500,000 MESF) at the same instrument settings as for samples analysis.
*MESF: Molecules of Equivalent Soluble Fluorochrome
6. Construct calibration curve by plotting MESF (y-axis) vs. the Geometric Means (x-axis).
7. The number of molecules per cell was determined using the following equation: $y=ax^b$ where y is equal to MESF and x is equal to Mean Channel Fluorescence of the sample. Mean Channel Fluorescence used for each sample was the Geo Mean at saturation concentration (12.12FITC) or the highest concentration (rituximabFITC).
8. Dividing MESF of sample by the numbers of FITC molecules conjugated to each antibody (F:P ratio) to determine the antibody binding capacity (ABC). ABC of huIgGFITC of respected sample was corrected to obtain the final antibody binding capacity.

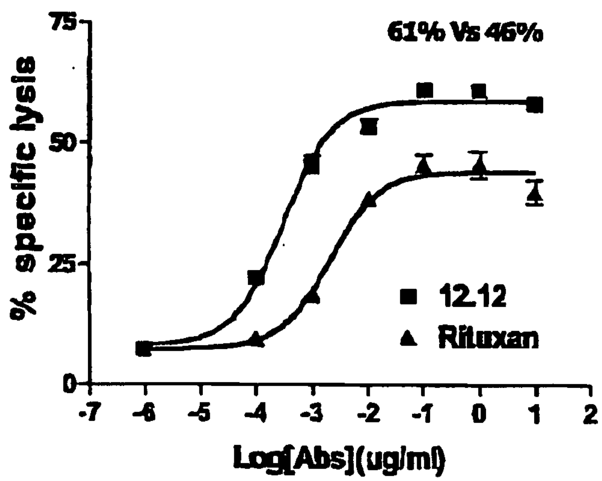
	Daudii		Namalwa	
Exp.	**CD40**	**CD20**	**CD40**	**CD20**
E090403	14403.0	93676.5	3296.4	6200.1
E091003	13214.9	108438.5	3081.5	4788.2
E091103	13702.6	100509.1	3165.7	3988.3
E091203	13278.9	128158.3	3164.9	4618.0
Average	**13,649.9**	**107,695.6**	**3,177.1**	**4,898.7**
Stdev	546.7	14915.9	88.8	933.4

FIG. 8

FIG. 9







ED50 (pM)

Exp	12.12	Rituximab
20	2.09	13.99
28	2.17	27.15
29	4.08	64.42

Effector cells: purified NK cells from healthy human volunteers.
E:T ratio : 10

FIGURE 10A

Amino Acid Sequences 12.12

12.12 Light chain:

leader:MALPAQLLGLLMLWVSGSSG
variable:
DIVMTQSPLSLTVTPGEPASISCRSSQSLLYSNGYNYLDWYLQKPGQSPQVLISLGSNR
ASGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCMQARQTPFTFGPGTKVDIR
constant:
RTVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQ
DSKDSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC*

FIGURE 10B

12.12 Heavy chain:

leader:MEFGLSWVFLVAILRGVQC
variable:
QVQLVESGGGVVQPGRSLRLSCAASGFTFSSYGMHWVRQAPGKGLEWVAVISYEESNRY
HADSVKGRFTISRDNSKITLYLQMNSLRTEDTAVYYCARDGGIAAPGPDYWGQGTLVTV
SS
constant:
ASTKGPSVFPLAPASKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQS
SGLYSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELL
GGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREE
QYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPP
SREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTV
DKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK*
or

alternative constant region:
ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQS
SGLYSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELL
GGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREE
QYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPP
SREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTV
DKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK*

FIGURE 11A

Amino Acid Sequence for 5.9
<u>5.9 Light chain</u>:

leader:MALLAQLLGLLMLWVPGSSG
variable:
AIVMTQPPLSSPVTLGQPASISCRSSQSLVHSDGNTYLNWLQQRPGQPPRLLIYKFFRR
LSGVPDRFSGSGAGTDFTLKISRVEAEDVGVYYCMQVTQFPHTFGQGTRLEIK
constant:RTVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSG
NSQESVTEQDSKDSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC*

FIGURE 11B

<u>5.9 Heavy chain</u>:

leader:MGSTAILALLLAVLQGVCA
variable:EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGI
IYPGDSDTRYSPSFQGQVTISADKSISTAYLQWSSLKASDTAMYYCARGTAAGRDYYYY
YGMDVWGQGTTVTVSS

constant region:
ASTKGPSVFPLAPASKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQS
SGLYSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELL
GGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREE
QYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPP
SREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTV
DKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK*

or alternative constant region:

ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQS
SGLYSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAPELL
GGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREE
QYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPP
SREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTV
DKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK

FIGURE 12A

DNA sequence of Light chain of 12.12

5'atggcgctccctgctcagctcctggggctgctaatgctctgggtctctggatccagtggggatattgtgatgactcagtctccac
tctccctgaccgtcacccctggagagccggcctccatctcctgcaggtccagtcagagcctcctgtatagtaatggatacaactat
ttggattggtacctgcagaagccagggcagtctccacaggtcctgatctctttgggttctaatcgggcctccggggtccctgacag
gttcagtggcagtggatcaggcacagattttacactgaaaatcagcagagtggaggctgaggatgttggggtttattactgcatgc
aagctcgacaaactccattcactttcggccctgggaccaaagtggatatcagacgaactgtggctgcaccatctgtcttcatcttcc
cgccatctgatgagcagttgaaatctggaactgcctctgttgtgtgcctgctgaataacttctatcccagagaggccaaagtacagt
ggaaggtggataacgccctccaatcgggtaactcccaggagagtgtcacagagcaggacagcaaggacagcacctacagcc
tcagcagcaccctgacgctgagcaaagcagactacgagaaacacaaagtctacgcctgcgaagtcacccatcagggcctgag
ctcgcccgtcacaaagagcttcaacaggggagagtgttag3'

FIGURE 12B

DNA sequence of Heavy chain of 12.12 (including introns)

5'atggagtttgggctgagctgggttttccttgttgctattttaagaggtgtccagtgtcaggtgcagttggtggagtctgggggag
gcgtggtccagcctgggaggtccctgagactctcctgtgcagcctctggattcaccttcagtagctatggcatgcactgggtccg
ccaggctccaggcaaggggctggagtgggtggcagttatatcatatgaggaaagtaatagataccatgcagactccgtgaagg
gccgattcaccatctccagagacaattccaagatcacgctgtatctgcaaatgaacagcctcagaactgaggacacggctgtgta
ttactgtgcgagagatgggggtatagcagcacctgggcctgactactggggccagggaaccctggtcaccgtctcctcagcaa
gtaccaagggcccatccgtcttccccctggcgcccgctagcaagagcacctctgggggcacagcggccctgggctgcctggt
caaggactacttccccgaaccggtgacggtgtcgtggaactcaggcgccctgaccagcggcgtgcacaccttcccggctgtcc
tacagtcctcaggactctactccctcagcagcgtggtgaccgtgccctccagcagcttgggcacccagacctacatctgcaacgt
gaatcacaagcccagcaacaccaaggtggacaagagagttggtgagaggccagcacagggagggagggtgtctgctggaa
gccaggctcagcgctcctgcctggacgcatcccggctatgcagtcccagtccagggcagcaaggcaggccccgtctgcctctt
cacccggaggcctctgcccgccccactcatgctcagggagagggtcttctggctttttccccaggctctgggcaggcacaggct
aggtgcccctaacccaggccctgcacacaaaggggcaggtgctgggctcagacctgccaagagccatatccgggaggaccc
tgcccctgacctaagcccaccccaaaggccaaactctccactccctcagctcggacaccttctctcctcccagattccagtaactc
ccaatcttctctctgcagagcccaaatcttgtgacaaaactcacacatgcccaccgtgcccaggtaagccagcccaggcctcgc
cctccagctcaaggcgggacaggtgccctagagtagcctgcatccagggacaggccccagccgggtgctgacacgtccacct
ccatctcttcctcagcacctgaactcctggggggaccgtcagtcttcctcttccccccaaaacccaaggacaccctcatgatctcc
cggacccctgaggtcacatgcgtggtggtggacgtgagccacgaagaccctgaggtcaagttcaactggtacgtggacggcg
tggaggtgcataatgccaagacaaagccgcgggaggagcagtacaacagcacgtaccgtgtggtcagcgtcctcaccgtcct
gcaccaggactggctgaatggcaaggagtacaagtgcaaggtctccaacaaagccctcccagcccccatcgagaaaaccatc
tccaaagccaaaggtgggacccgtggggtgcgagggccacatggacagaggccggctcggcccaccctctgccctgagagt
gaccgctgtaccaacctctgtccctacagggcagccccgagaaccacaggtgtacaccctgcccccatcccgggaggagatg
accaagaaccaggtcagcctgacctgcctggtcaaaggcttctatcccagcgacatcgccgtggagtgggagagcaatgggc
agccggagaacaactacaagaccacgcctcccgtgctggactccgacggctccttcttcctctatagcaagctcaccgtggaca
agagcaggtggcagcaggggaacgtcttctcatgctccgtgatgcatgaggctctgcacaaccactacacgcagaagagcctc
tccctgtctccgggtaaatga3'

FIGURE 13A

Coding sequence for human CD40:

1 atggttcgtc tgcctctgca gtgcgtcctc tggggctgct tgctgaccgc tgtccatcca
61 gaaccaccca ctgcatgcag agaaaaacag tacctaataa acagtcagtg ctgttctttg
121 tgccagccag gacagaaact ggtgagtgac tgcacagagt tcactgaaac ggaatgcctt
181 ccttgcggtg aaagcgaatt cctagacacc tggaacagag agacacactg ccaccagcac
241 aaatactgcg accccaacct agggcttcgg gtccagcaga agggcacctc agaaacagac
301 accatctgca cctgtgaaga aggctggcac tgtacgagtg aggcctgtga gagctgtgtc
361 ctgcaccgct catgctcgcc cggctttggg gtcaagcaga ttgctacagg ggtttctgat
421 accatctgcg agccctgccc agtcggcttc ttctccaatg tgtcatctgc tttcgaaaaa
481 tgtcaccctt ggacaaggtc cccaggatcg gctgagagcc ctggtggtga tccccatcat
541 cttcgggatc ctgtttgcca tcctcttggt gctggtcttt atcaaaaagg tggccaagaa
601 gccaaccaat aa

FIGURE 13B

Encoded human CD40:

1 mvrlplqcvl wgclltavhp epptacrekq ylinsqccsl cqpgqklvsd cteftetecl
61 pcgesefldt wnrethchqh kycdpnlglr vqqkgtsetd tictceegwh ctseacescv
121 lhrscspgfg vkqiatgvsd ticepcpvgf fsnvssafek chpwtrspgs aespggdphh
181 lrdpvchplg aglyqkggqe anq
//

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